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Fisheries and Wildlife Research and Development

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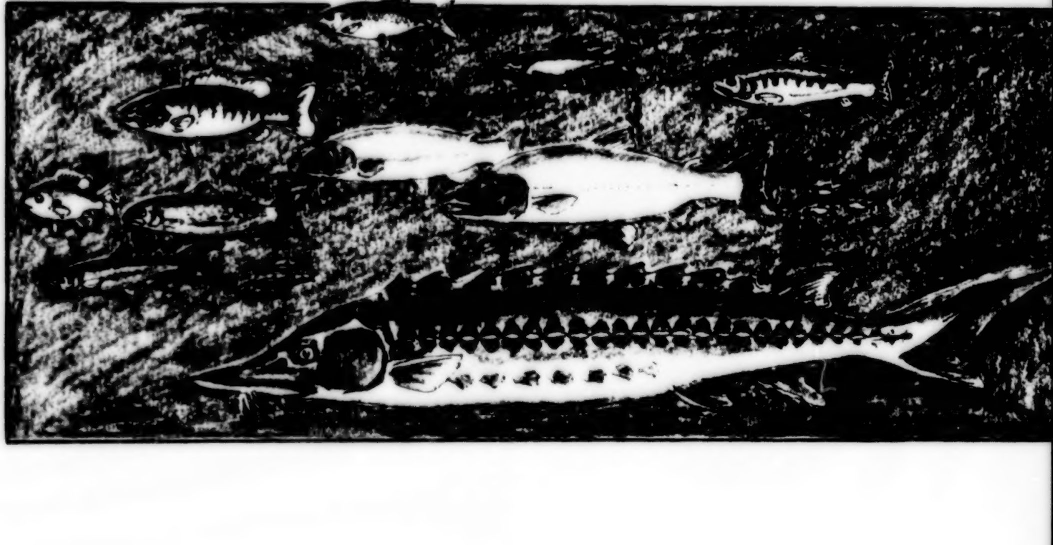

U.S. DEPARTMENT OF THE INTERIOR / NATIONAL BIOLOGICAL SERVICE

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A $6\frac{1}{2}$-year old female brown bear in Alaska.

Fisheries and Wildlife Research and Development 1991/1992

Activities in Region 8–Research and Development–for
Fiscal Years 1991 and 1992

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Foreword

The personnel of the Research and Development Region (Region 8) of the U.S. Fish and Wildlife Service joined with other biological and related scientists from other Interior agencies to form the National Biological Service in November 1993. The research presented in this biennial report was accomplished under the direction of the U.S. Fish and Wildlife Service during 1991 and 1992. The U.S. Fish and Wildlife Service remains an important client agency of the National Biological Service. The National Biological Service expects to provide biological research in support of its client agencies within the Department of the Interior.

A Preamble to Change

On 11 November 1993 the National Biological Service became operational. The National Biological Service was formed by merging the biological research, inventory and monitoring, and information transfer programs of the U.S. Fish and Wildlife Service, the National Park Service, the Bureau of Land Management, the Minerals Management Service, the U.S. Geological Survey, the Bureau of Reclamation, and the Office of Surface Mining. Most employees of the National Biological Service were formerly with the U.S. Fish and Wildlife Service and the National Park Service. The material in this 1991–92 biennial report on research by the U.S. Fish and Wildlife Service represents the final report of the Service-led program of Research and Development (Region 8). The National Biological Survey will continue to do research of interest to its seven client agencies in the U.S. Department of the Interior and will broaden the base of research to ecosystems and communities that may be larger than the holdings of a single federal agency. The new agency sincerely appreciates the base of information and scientists from the contributing agencies and is pleased to contribute this 1991–92 biennial report to the record of accomplished research by the U.S. Fish and Wildlife Service detailed in previous annual and biennial reports. This completes the record of research by U.S. Fish and Wildlife Service scientists.

Introduction

The Role of Research

> "As we approach the 21st century, America's fish and wildlife resources are confronted by an increasing complex combination of factors. The continued growth of our population, economy, and technology places even greater stresses on natural systems and the species they support..."

The Director of the Fish and Wildlife Service recognized that research is crucial to our understanding of the natural world. Without the ability to analyze and evaluate natural systems and the species they support, the Fish and Wildlife Service could not fulfill its stewardship responsibility. The Director noted the unique abilities of agency scientists.

> "The Service can perform national research, data collection and analysis, and develop the data base necessary for long-term management of transboundary species and resource problems."

Research is the first step in the journey toward natural resource management and protection. The ability of agency scientists to study and interpret biological processes is the foundation on which Fish and Wildlife Service operations rest. Research scientists, who are proficient in both applied and basic research, conduct research for the Fish and Wildlife Service and other Federal agencies. Strategically located in 13 research centers and 90 field stations across the country, and the Information Transfer Center in Fort Collins, Colorado, scientists provide technical assistance to other Service personnel, to State agency personnel, and to personnel of other Federal agencies. And as part of the agency's outreach efforts, education and training are presented to hundreds of students annually.

The expertise of agency scientists spans the environmental spectrum. With almost 500 scientists, half of whom have Ph.D's, agency scientists have more than 4,000 *years* of Federal research experience. Disciplines include biology (mammals, birds, fishes, amphibians, and reptiles), limnology, ecology, microbiology, physiology, virology, hydrology, toxicology, genetics, statistics, chemistry, geography, computer systems, technical information, and management and policy. Agency scientists conduct research on environmental contaminants, migratory birds, marine mammals, population ecology, ecological communities and habitats, fish husbandry, and disease diagnosis and control.

Ongoing Research

More than 11 Acts of Congress authorize research by the Fish and Wildlife Service. To meet the expectations of Congress, agency experts are working on the most important biological challenges facing the nation.

Wetlands

Wetlands provide habitat, shelter, and food for the Nation's waterfowl, for 80% of the Nation's recreational and commercial fisheries, for more than 75% of the endangered animal species, and for countless other species. The Fish and Wildlife Service provides national leadership in understanding, conserving, restoring, and managing wetlands. Agency scientists, along with scientists from the U.S. Geological Survey, the National Oceanographic and Atmospheric Administration, and academia, have developed the Nation's primary wetlands classification system.

Global Change

World leaders continue to debate the economic and social implications of global environmental changes, both natural and human-induced. Climate change may have significant effects on the fish and wildlife resources for which the Fish and Wildlife Service has stewardship responsibility. To understand those effects, the Fish and Wildlife Service joined the United States Global Change Research Program to measure the state and direction of global change and to predict its effects on fish and wildlife.

Biodiversity

Conservation of biological diversity has emerged as a dominant resource management issue. On the cutting edge of biodiversity protection, agency scientists have pioneered state-of-the-art natural resource assessment systems such as "Gap Analysis," that provide land management agencies, conservation groups, and other interested parties with information needed to fill "gaps" in the protective network of managed habitats. Agency scientists are also in the forefront on issues relating to genetic diversity and tools for characterizing species and populations.

Exotic Nuisances

Nonindigenous species have continued to enter the United States during the last decade at alarming rates, disturbing native communities and causing economic damage. Agency scientists have been working on methods to control species such as purple loosestrife, zebra mussel, brown tree snake, sea lamprey, and European ruffe.

Waterfowl

Researchers shed light on the problem of declining waterfowl productivity by understanding the effects of intensive farming in breeding areas and how these activities increase waterfowl nest predation by small mammals. These same individuals are working to learn the most effective ways to use landscapes including corridors, field sizes, and habitat manipulation (nesting cover, islands, peninsulas, nest baskets) to improve waterfowl production. Major contributions to knowledge have been made throughout the annual cycle of mallards and canvasbacks. Special emphasis on wintering grounds on all major flyways has increased our knowledge of waterfowl requirements during that period. A shift in habits of wintering Canada geese to spend more time as resident populations rather than migrate has been identified and is now a major management concern. Other waterfowl studies are addressing specifics of winter habitat use, annual survival, and year-around energetics of ducks and geese.

Fisheries

Fishery scientists are focusing attention on the Great Lakes, the great rivers, and the coastal habitats. Increasing returns of Atlantic salmon, preventing further stock reductions of anadromous species in Western rivers, and maintaining natural diversity in wild stocks are high priorities for agency research efforts.

Contaminants, Diseases, and Biotechnology

Agency scientists conducted early research on DDT and developed a sophisticated contaminant research program, including hazards assessment modeling. Breakthroughs have been made in disease research including fish whirling disease and the avian botulism cycle. New insights have been gained into fish diets and nutrition, safe use of chemical sterilants as a sea lamprey control mechanism, use of genetic markers for tracking fish populations and endangered species, and aquatic cycling of selenium. New applications have made use of high technology such as satellites for animal tracking and providing images for geographic information system (GIS) applications to fish and wildlife science.

Habitats

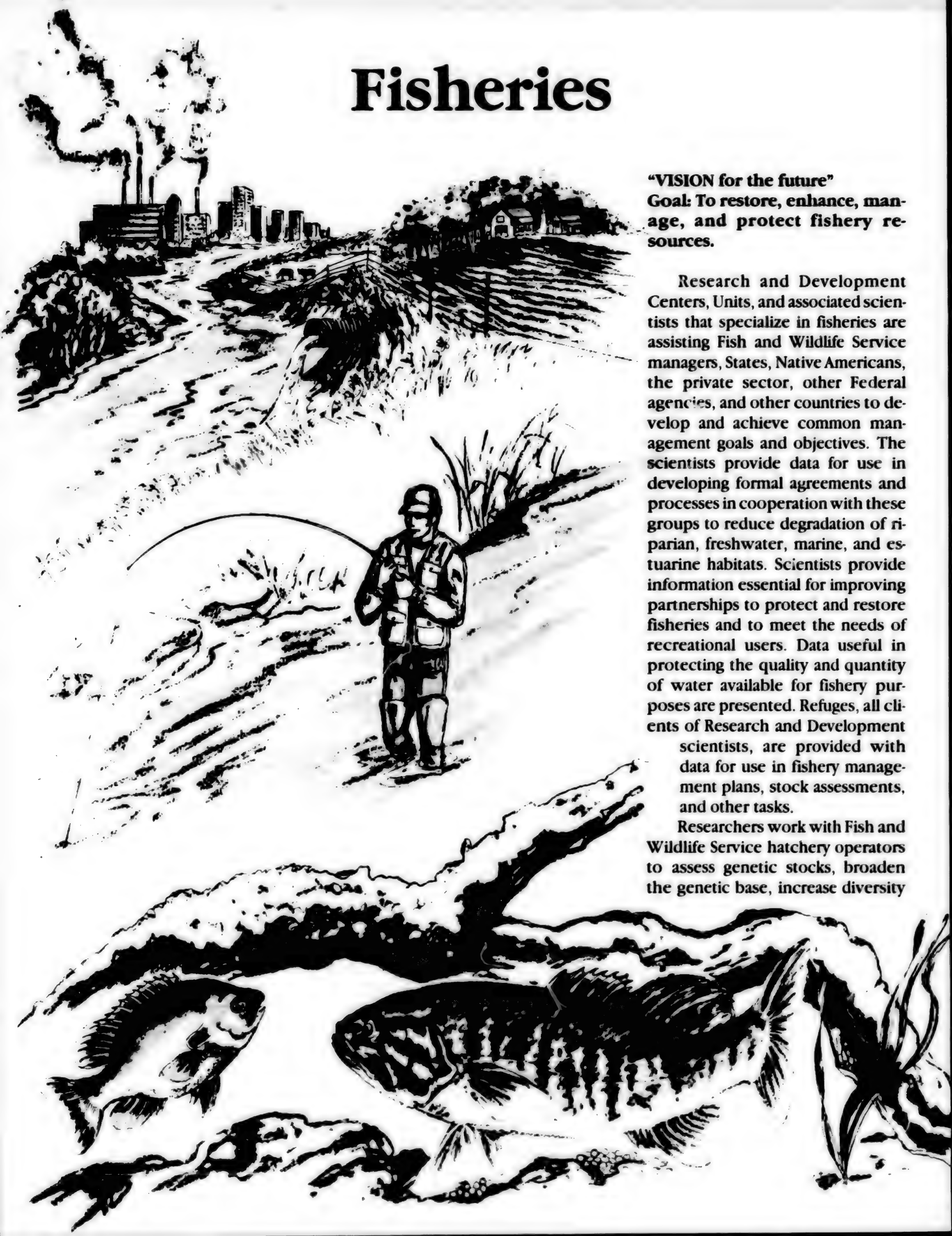
In addition to wetlands, agency scientists are studying old-growth forests, riparian vegetation, prairie grasslands, aquatic habitats, and habitat fragmentation. Much progress has been made in integrating population and habitat studies from microhabitats to landscapes.

The agency's expertise is unlimited by borders and boundaries. Supported by innovative scientists, Research and Development provides international leadership in fish and wildlife management. Many agency scientists have experience in foreign countries, from Costa Rica to the Pacific Islands to the Commonwealth of Independent States. Language skills range from Norwegian to Kikongo.

Agency scientists also have seen the value of public outreach and extension and education efforts through the years. Particularly in an era of greater environmental awareness in the United States, the agency contributes extension specialists, technical information specialists, writers, editors, librarians, training specialists, and visual information specialists to improve the Nation's understanding of and appreciation for fish and wildlife.

Photo by K. W. Kenyon.

Fisheries



"VISION for the future"
Goal: To restore, enhance, manage, and protect fishery resources.

Research and Development Centers, Units, and associated scientists that specialize in fisheries are assisting Fish and Wildlife Service managers, States, Native Americans, the private sector, other Federal agencies, and other countries to develop and achieve common management goals and objectives. The scientists provide data for use in developing formal agreements and processes in cooperation with these groups to reduce degradation of riparian, freshwater, marine, and estuarine habitats. Scientists provide information essential for improving partnerships to protect and restore fisheries and to meet the needs of recreational users. Data useful in protecting the quality and quantity of water available for fishery purposes are presented. Refuges, all clients of Research and Development scientists, are provided with data for use in fishery management plans, stock assessments, and other tasks.

Researchers work with Fish and Wildlife Service hatchery operators to assess genetic stocks, broaden the genetic base, increase diversity of the hatchery product, and evaluate means of improving survival of hatchery fish stocks before and after release. National repositories for fisheries and associated data are established at several centers. Genetics, disease, nutrition, habitat selection and use, nuisance fishes, and restoration of endangered species are important to researchers and Fish and Wildlife Service fishery managers.

Numerous studies involving follow-up to stocking of hatchery fish, restoration of fish habitats, and assessments of habitats related to mitigation have been completed or are under way. Several fish nutrition and pond management techniques to increase production in private aquaculture activities have been completed. Fish and Wildlife Service scientists and facility managers are making individual and collective efforts to meet the great need to provide educational materials and presentations to improve environmental awareness in support of fish conservation. Much attention is given to habitat quality and the effects of change on maintaining a high-quality environment for fishery resources.

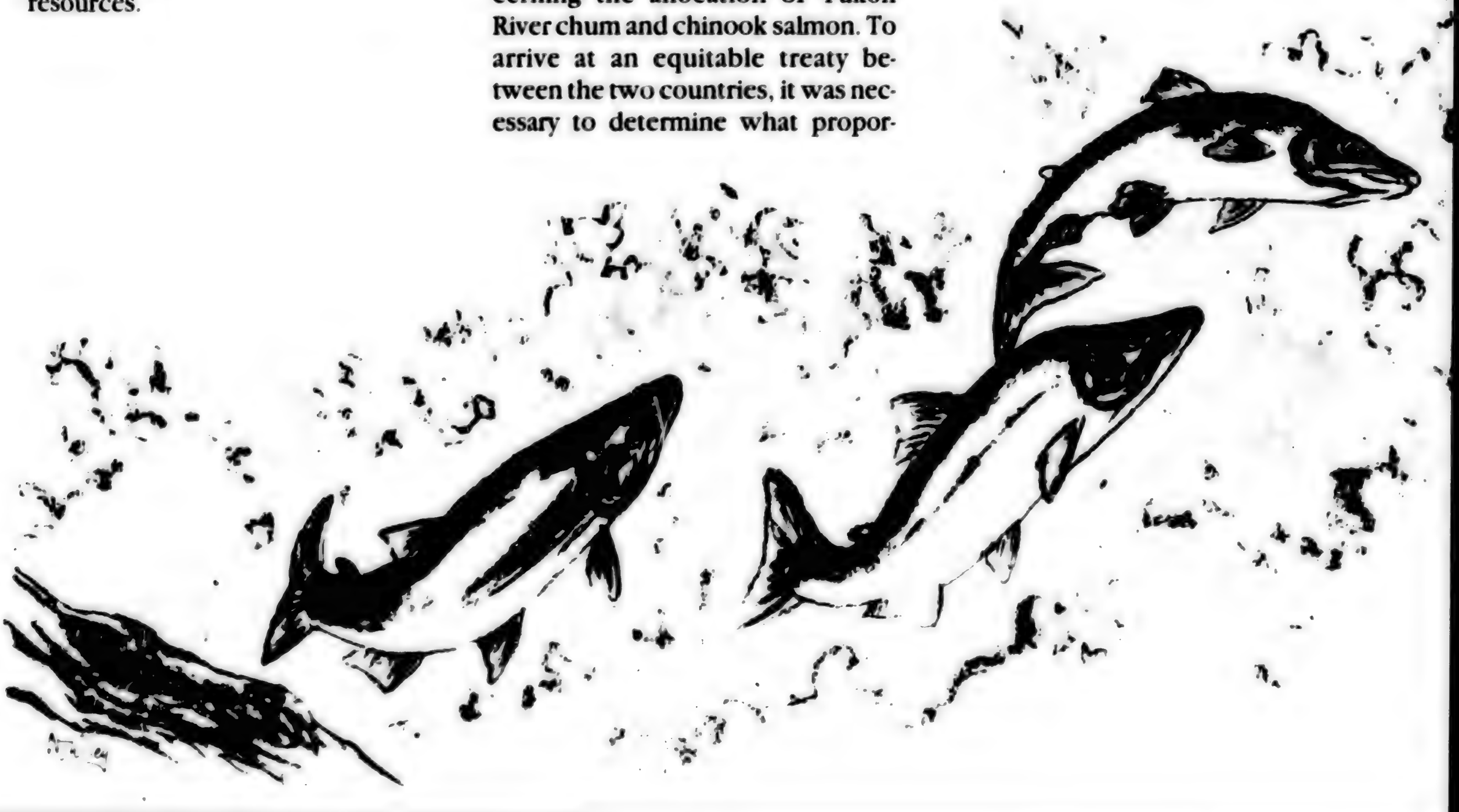
Anadromous Fishes

Effects of Stocking on Natural Populations

Scientists at the Alaska Fish and Wildlife Research Center–Anchorage, initiated a multi-year investigation of sockeye salmon in the Tustumena Lake watershed in 1989 to determine the effects of hatchery supplementation on spawning of wild fish and genetic biodiversity of the lake population. Each year about 30% of the sockeye salmon escapement spawned along the lake's shoreline, an indication of natural spawning. Preliminary results showed that juvenile sockeye salmon populations at Tustumena were synchronous with sockeye salmon dynamics in other lakes.

Genetic Stock Identification Separates United States–Canadian Fishes

In 1985, the United States and Canada began negotiations concerning the allocation of Yukon River chum and chinook salmon. To arrive at an equitable treaty between the two countries, it was necessary to determine what proportion of the United States catch was of Canadian origin. Genetic stock identification (GSI), a proven method used on the west coast of North America to provide direct estimates of stock contributions to mixed stock salmon fisheries, was used by the Alaska Fish and Wildlife Research Center to characterize chum and chinook salmon stocks in the Yukon River. Cooperators included the Fish and Wildlife Service's Alaska Region Fisheries Management, the Alaska Department of Fish and Game, and biologists in Canada. The origin of chum salmon harvested over the 4-year period ranged from 82% to 91% for United States summer-run fish, from 6% to 11% for United States fall-run fish, and from 3% to 8% Canadian fall-run fish. Based on the fall-run fish only, United States-origin fish in the catch ranged from 54% to 68% and Canadian-origin fish ranged between 32% and 46%. The percentages translate to an average of 347,057 United States-origin summer-run fish, 33,216 United States-origin fall-run fish, and 22,210 Canadian-origin fall-run fish.



Maintaining Genetic Diversity

Researchers at the National Fisheries Research Center–Seattle, Washington, conducted studies to assist the Fish and Wildlife Service in conserving the genetic resources of anadromous salmonids. A study of the genetic structure of steelhead in Oregon and northern California using starch-gel electrophoresis showed north to south clines in allele frequencies at several gene loci, a pattern similar to steelhead in northwestern Washington. Allele frequencies did not differ among adjacent drainages, and variation was substantially less than seen by other workers for steelhead in British Columbia. Most hatchery populations were significantly different from wild populations, suggesting that few wild fish were successfully included in hatchery brood stocks.

Genetic variability is absent in most hatchery populations of fish, partially because the populations are not supplemented with fish from other populations. Hatchery populations of anadromous salmonids, however, frequently include "strays" from other populations, and may retain some genetic variability. Allozyme frequencies were compiled from three studies and compared to the heterozygosities of hatchery and nearby wild populations of chinook and coho salmon and steelhead. Hatchery populations were significantly less heterozygous than were wild populations. The apparent loss of genetic variability in hatchery populations brought forth suggestions that hatchery managers, (1) avoid selective breeding, (2) adjust practices to increase effective population size, and (3) regularly include wild fish in brood stock. Fishery management must conserve genetic variability of wild stocks so that reservoirs of genetic variation remain available.

Modeling Fish Habitat and Production Interactions

Personnel at the National Ecology Research Center–Fort Collins, Colorado, in conjunction with local river system experts developed a conceptual model for exploring how habitat affects the production of juvenile chinook salmon in the Trinity River in northern California. The model tracks fish numbers, age structure, and growth through the year. The model incorporates switches and rates for mortality, natality, and migration or movement that are limited by the capacity of the habitat (bottlenecks) and by the influence of water temperature on growth. The model uses Instream Flow Incremental Methodology, which describes the amount of habitat for each life stage as a function of water flow through both time and space. The conceptual model is a first-generation computer model with outputs that help identify the most significant limiting events.

Turbine Mortality versus Predation Losses

Scientists at the Columbia River Field Station of National Fisheries Research Center–Seattle studied northern squawfish predation on live and dead juvenile salmonids in the Bonneville Dam tailrace. Juvenile salmonids injured or killed during passage past dams may be highly vulnerable to or preferred food of predators aggregated below dams. Consequently, estimates of losses to predation based on stomach analyses from predators congregated below dams may be too high. Field experiments were conducted in 1991 below Bonneville Dam on the Columbia River to compare predation rates by northern squawfish on live versus dead juvenile salmonids. Known numbers of coded-wire tagged (CWT) live and dead chinook salmon were released into the tailrace on 6 nights. Northern squawfish were collected by electrofishing from a boat after each release, and 740 digestive tracts were examined for CWT's. When 10% of salmon released were dead, 22% of the CWT's in predator's guts were from dead salmon. When 50% of the released salmon were dead, 60% of CWT's were from dead salmon. The larger northern squawfish (>300 mm fork length) captured more dead salmon than did smaller predators. The number of juvenile salmonids killed by turbines must be known to accurately estimate losses of salmonids to northern squawfish predation if analysis of food habitats is used as a basis for the estimate.

Riverine Habitat Use by Juvenile Salmonids

Researchers at the California Cooperative Fishery Research Unit compared macroinvertebrate benthos and drift and juvenile salmonid populations in two side-channels to mainstem sites on the upper Trinity River in California. The river had a higher standing benthic biomass than the side-channels, largely because of the abundance of a fast-water dwelling invertebrate. Drift insect abundance did not differ significantly between sites. Juvenile coho salmon used the side-channels extensively year round; juvenile chinook salmon used the side-channels in spring, summer, and fall; juvenile steelhead used the side-channels and the main river equally; juvenile brown trout used the side-channels more during winter. Lower water velocities, warmer winter temperatures, and cooler summer temperatures seemed to account for the extensive use of side-channels by juvenile salmonids.

Unit scientists determined food sources and food habits of juvenile chinook salmon in the Mattole River Estuary that subsequently became a lagoon. Epibenthos samples were dominated by an amphipod; plankton increased in abundance after the lagoon formed, and copepods were abundant at times. Juvenile chinook consumed mostly terrestrial and aquatic insects early in summer; fly larvae and adults comprised most of the diet later. Juvenile chinook relied mostly on imported food items from riverine and windborne sources and fed little on epibenthos.

Atlantic Salmon Restoration

Atlantic salmon restoration programs in New England were hampered in part by high rates of exploitation in foreign fisheries and mortality that happened between smolt release and commencement of foreign fishing. National Fisheries Research Center–Leetown, West Virginia, scientists developed a run-reconstruction model of Maine stocks to allow assessment of the relative importance of distant fisheries on the restoration program. Analyses of tag recovery data from 1968 to 1991 revealed average total exploitation rates on the Maine stocks in excess of 50%.

To determine whether Atlantic salmon survive and smoltify in the Merrimack River, researchers from the National Fishery Research and Development Laboratory–Wellsboro, Pennsylvania, recorded mortality from early April to late June in 1988 and 1989 for hatchery fish held in 122 × 46 × 61 cm stationary and movable cages at three sites for up to 70 days. Mortality gradually increased through the season but was highest during rising and sustained elevated temperatures in late May. Although extremes in temperature and salinity were greatest at the freshwater–seawater site, mortality was lowest in the stationary cage at this site. Analysis of disease and mortality data suggests that the sooner a fish leaves the river and enters seawater the better are its chances of surviving, especially late in the season when river flows are low. At this time, water temperatures may approach lethal levels or reach levels that interfere with smoltification and migration.

Restoring Atlantic Salmon by Using Only Females

All-female Atlantic salmon for restoration programs were produced by researchers at the National Fishery Research and Development Laboratory–Wellsboro using gynogenesis only. In early attempts, 100% female progeny were produced, but only 7% successfully hatched. A combination of gynogenesis followed by sex-reversal produced XX-males that when mated with normal females, yielded 100% female progeny with normal hatching rates.

Non-lethal Gill Biopsy

Biologists at National Fisheries Research Center–Leetown Conte Anadromous Fish Research Center, Turner Falls, Massachusetts, developed a non-lethal method of gill biopsy and measurement of Na^+,K^+-ATPase in small amounts of gill tissue. Na^+,K^+-ATPase is a critical enzyme for ionic regulation in seawater. The method is useful for monitoring of physiological smolt characteristics in salmonids, and may have application in the studies of disease, toxicology, and physiological ecology of many fish species.

Marking to Identify Individuals

Identifying recaptured fish is essential to the evaluation of fish restoration programs. Scientists at National Fishery Research and Development Laboratory–Wellsboro compared readability of a tag implanted under the eyelid tissue in Atlantic salmon and lake trout and evaluated fin-clipping in striped bass at 5 months of age as methods of identifying fishes. The tag remained readable in Atlantic salmon throughout the 2-year study, but the eyelid tissue of the trout thickened and developed pigmentation, making 90% of the tags unreadable after 6 months in place. Fins partially regenerated in striped bass, but were clearly visible on 88% of fish after 12 months.

In cooperation with Northeast Region Chesapeake Bay personnel and the Maryland Department of Natural Resources, biologists at National Fisheries Research Center–Leetown evaluated different internal anchor tags for retention and post-tagging survival of phase II striped bass. Tag design, location on the body, and skill of the tagger influenced retention and survival.

In a related study, two size classes of striped bass were marked by scientists from National Fisheries Research Center–Leetown with the recently developed visual implant (VI) tag, a small strip of individually coded, inert material implanted under an area of clear tissue. Several locations where the tissue seemed to be of acceptable transparency were evaluated: near the eye, on the lower opercle, and in the fin membrane of large fish only. Although no apparent stress, disease, or mortality were associated with the tags, retention was 18% or less in all implantation locations after 1 year. The visual implant tags were considered unacceptable for use in striped bass.

Atlantic salmon with visible implant tag. *Photo by H. L. Kincaid.*

American Shad

Releasing of American shad larvae is a major component of a program to restore shad in the Susquehanna River. Researchers at the National Fishery Research and Development Laboratory–Wellsboro worked with fish managers and culturists to determine ways to improve the post-stocking survival of American shad.

Researchers defined behaviors of larval-to-juvenile American shad to develop concepts for passage facilities at dams and strategies to enhance larval stocking. Early larval shad exhibited 12 discrete behavioral patterns. Schooling and other cohesive behavior developed during the early juvenile stage, but stereotypical feeding behaviors that increased feeding efficiency did not develop until the late larval stage. Thus, larval shad seemed to act independently, while sociability developed with juveniles. Respiratory rates of juveniles in large (>50) schools were significantly lower than those of fish in small groups that did not school.

The use of known fish spawn-induction hormones on American shad suggested that two injections of 4–5 g $LHRH_a$ per kilogram of fish within a 12-h period induced ovulation. Fish containing large transparent eggs ovulated within 12 h of the first injection.

Research also was conducted to determine how predation and riverine food supply affects survival following release. Predation was substantial at the release site and for at least 100 m downstream. Twenty-one species consumed larval shad. Several species of extremely abundant minnows formed the major predatory group. Preliminary documentation of predation led managers and culturists to experiment with day versus night stocking.

White Sturgeon Between Bonneville and McNary Dams

Biologists at the National Fisheries Research Center–Seattle sampled early life-history stages of white sturgeon in the Columbia River pools between Bonneville and McNary dams during 1991. White sturgeon spawned in the tailraces of dams at water temperatures of 12.0–19.1° C. Newly deposited eggs (less than 3 h old) were collected at water velocities of 0.9–2.1 m/s. Twenty-one percent of the 412 eggs collected in Bonneville Pool were non-viable compared with 23% of 334 eggs in The Dalles Pool, and 36% of 29 eggs in John Day Pool.

As in previous years, more larval white sturgeon were collected in Bonneville Pool (183) than in The Dalles Pool (53), or John Day Pool. Young-of-the-year white sturgeon collected in Bonneville Pool accounted for 92% of the total catch from all pools in 1991. Young-of-the-year white sturgeon were collected in all three pools at depths of 13.4–57.3 m, over sand, mud, gravel, and cobble substrates.

Eighty-three percent of all juvenile white sturgeon collected in 1991 were caught in the Bonneville Pool. Juvenile white sturgeon were collected from water depths ranging from 8.2 to 49.6 m, from water velocities ranging from 0.1 to 1.2 m/s, and over substrates ranging from silt to cobble.

Sturgeon in the Suwannee River and Estuary

The National Fisheries Research Center–Gainesville, Florida, began studies in 1988 to determine the life history and seasonal abundance of gulf sturgeon in the Suwannee River and the estuarine waters of the Lower Suwannee National Wildlife Refuge. About 1,500 sturgeon were marked with external tags and passive integrated transponders (PIT tags) and released to provide growth and movement information and to estimate population size. Also, 99 sturgeon were equipped with temperature-sensing radio transmitters to help identify preferred habitats and migration patterns.

Data on nearly 200 marked sturgeon indicated they spend 8–9 months in the river and 3–4 of the coolest months near the river mouth or in the Gulf of Mexico. Sturgeon that were free at least 12 months grew 9–12 cm each year, and those that weighed between 7 and 27 kg gained 2–3 kg annually. Sturgeon that were marked and recaptured during the same summer lost weight. Subadult and adult sturgeon fed and gained weight during winter and spring while in offshore or estuarine waters and, despite ample food, fasted and lost weight when in fresh water.

Great Lakes Fisheries

Lake Superior Wild Strains

The lake trout reproduces widely only in Lake Superior, though extensive restoration efforts occur throughout the Great Lakes. Three recognizable forms of lake trout in Lake Superior differ in facial and skull features, fat content, and reproductive habits. The lean trout has low body fat levels and inhabits inshore waters shallower than 70 m. The siscowet trout has high body fat levels and inhabits offshore waters deeper than 80 m. The humper trout also has high body fat levels and inhabits isolated offshore mounts about 50 m deep.

Morphological differences among the three forms were mostly phenotypic, but controlled hatchery experiments showed a genetic basis as well. Mitochondrial DNA analyses showed that genetic material flowed among the three forms in Lake Superior. Divergence between forms was comparable to those of other trout and salmon. A 90% difference in facial and skull bones of siscowet–humper and lean trout further supported a genetic difference. Physical separation of these races during spawning was nearly complete, though limited interbreeding was found. Isolation precedes development of these forms into species within Lake Superior.

Hatchery Strain Management

The Green Lake strain of lake trout was last planted into Lake Michigan in 1976. It was the last remaining strain of deep-spawning lake trout that once populated southern Lake Michigan. In 1985, Fish and Wildlife Service and State biologists began a 3-year cooperative effort to develop a brood stock of deep-spawning fish from recaptured feral fish that returned to spawning reefs in southern Lake Michigan. State biologists caught and spawned feral fish and transferred their gametes to the Charlevoix, Michigan, hatchery for rearing to maturity.

Electrophoretic analyses by Cornell University fish geneticists showed that the three year-classes were similar. Fish and Wildlife Service scientists from the National Fishery Research and Development Laboratory–Wellsboro developed a brood stock mating design that used within and between year–class matings to maintain genetic diversity. Initial matings were in October 1991, and egg production from offspring will begin in 1997.

Nuclear Cataract Research

Nuclear cataracts were found in as many as 60% of hatchery-reared lake trout. Researchers from the National Fishery Research and Development Laboratory–Wellsboro and the Allegheny National Fish Hatchery showed that decreased exposure to direct sunlight reduced cataract frequency. Fish held inside the hatchery or in fully shaded outside raceways had lower cataract frequencies than those held in partially shaded outside raceways. Cataracts developed at a faster rate in fish held in outside raceways.

Scientists from National Fishery Research and Development Laboratory–Wellsboro examined lake trout caught in Lake Ontario. In 1991, 42.3% of lake trout had nuclear cataracts. Seneca strain fish consistently had the highest rate of cataracts, and Superior strain fish had the lowest rate. Presence of cataracts did not affect growth. However, survival of fish with cataracts at the time of planting was lower after 26 months in the lake.

Lake Erie Gizzard Shad

Scientists at the Ohio Cooperative Fish and Wildlife Research Unit studied Lake Erie gizzard shad to determine young-of-year (YOY) production dynamics and predation by walleyes. Shad spawn between mid-April and the end of June. The growth rate of YOY shad was approximately 1 mm/day. Thus, shad that hatched on 1 June grew to 132 mm by 1 October. The 132-mm YOY were too large to be eaten by walleyes smaller than 600 mm. Current methods used for population assessment may not accurately characterize abundance of YOY shad because of their fast growth. The rapid growth of YOY shad probably caused population indices previously applied by biologists to underestimate the proportion of older shad.

A 14.7-inch sea lamprey and its victim, a rainbow trout. The trout died as a result of the feeding wound which penetrated the body cavity and severed the gut. The wound appears to the left of the lamprey.

Sea Lamprey Control

Lake Population Control

Adult sea lampreys spawn in many tributaries of the Great Lakes. Upon hatching, the non-parasitic larvae burrow into stream sediments, where they live for several years until they metamorphose into parasitic adults. Larvae are found mostly in streams, but aggregations were found where spawning streams enter lakes. Stream treatments with the chemical TFM have little effect on larvae at the lake-stream interface. Scientists at the National Fisheries Research Center–La Crosse, Wisconsin, developed an improved formulation of Bayluscide for control of larval lamprey in this habitat. A special process coats sand granules with Bayluscide and then with cellulose. The formulation sinks to the bottom, remains intact for about 10 minutes, and then releases the active ingredient near the bottom where the larval lampreys reside.

Field trials of the new formulation at the mouth of the Batchawana River near Lake Superior in Ontario, Canada, reduced larval sea lamprey numbers by 90%. The improved form released the active ingredient so quickly that larval lampreys were unable to swim away before receiving a lethal dose. The new formulation is safer for humans to use because it produces less dust during application.

Sterile-male Releases

Release of sterilized male sea lampreys into spawning streams aids recovery of lake trout populations in the Great Lakes. In May 1991, the Fish and Wildlife Service completed construction of a special facility to sterilize male sea lampreys. The facility design incorporated features that assure the safety of the workers and the environment. Filtration and other treatment of the water from the facility prevent release of sterilants or residues.

Immunology, radiation, and chemical sterilization were tested to find a method that will sterilize males without affecting their desire to spawn. Immunology and radiation techniques were not useful. Chemical sterilants are mutagenic and highly toxic, but seem efficient and practical. Bisazir, the chemical of choice, is considered environmentally safe because sea lampreys release the chemical from their bodies before leaving the facility. Therefore, Bisazir is recovered through the filtration system before lamprey release into spawning streams.

Fish and Wildlife Service employees worked with the Canada Department of Fisheries and Oceans to collect, sterilize, and release male sea lamprey spawners in the United States and Canada. More than 12,000 sterilized sea lampreys were released into Lake Superior tributaries and the St. Marys River. This program augmented chemical control in streams and provided a diversified approach to lamprey control.

Native versus Exotic Forage Fishes

Lake Superior

Native lake herring and exotic rainbow smelt were eaten by most major predators in Lake Superior. Herring numbers rebounded while smelt declined in the past few decades. The native forage species seemed to have gained the upper hand over the exotic species. Staff of the National Fisheries Research Center–Great Lakes estimated forage fish biomass and population changes in United States waters to evaluate the status of the fishery.

Historic lake herring yield exceeded all other species combined, although herring was the major food of lake trout. Catches in the United States peaked in 1941, declined slowly during the 1940's, then fell sharply through 1984. Fishing intensity caused the decline. Herring recovered slowly in 1985–86, then more rapidly in 1989–92. Several strong year–classes fueled the recovery.

Rainbow smelt entered the lake in the early 1930's and were abundant by the 1950's. Populations continued to increase through the 1960's and early 1970's. Increased predation caused smelt to decline more than 90% in the late 1970's and 1980's. Older fish disappeared from the population. Smelt populations are now smaller than in the past, and spawning success is low. Population declines will continue.

Lake Michigan

Native bloater chubs, slimy sculpins, deepwater sculpins, and exotic alewives and rainbow smelt are eaten by most predator fish in Lake Michigan. In the past decade, bloater populations have rebounded and alewife numbers have declined. Alewives dominated Lake Michigan from the mid-1960's through the early 1980's. Populations declined because of cold winters and increased predation by salmon and trout. In response, bloaters increased rapidly and now outnumber all other species. Deepwater sculpins also recovered, but have recently declined because of increasing predation by burbot. Slimy sculpins have declined in response to predation by both burbot and lake trout. Fish community modeling showed that large reductions in stocking of chinook salmon will help maintain alewives as a forage fish because chinooks consumed more alewives than the other salmonines combined.

The decline in exotic forage species in Lake Michigan allowed recovery of some native species, but global warming could ultimately favor the exotic alewives, which are more sensitive to low temperatures than native species.

Lake Huron

Native bloater chubs, exotic alewives, and rainbow smelt are eaten by most predator fish in Lake Huron. Bloaters increased and alewives declined in recent years. In contrast, smelt remained stable over the same period. In the 1970's, alewives and smelt dominated the forage fish community. By the late 1980's, bloaters had rebounded and alewives had declined. Bloater stocks remained strong though spawning success was low in 1990 and 1991. Alewives and smelt remained at lower levels, and young fish dominated the populations. The native species are expected to continue to increase.

Lake Erie (Western Basin)

Predator fishes in the western basin of Lake Erie eat emerald and spottail shiners, trout–perch, alewives, and gizzard shad. In 1991, shiners and trout–perch declined and alewives and shad increased compared to the previous decade. Reduced numbers of shiners and trout–perch were more than offset by increased numbers of alewives and shad. Growth of all species was better than in previous years. Reduced competition for food, a result of reduced overall abundances, is the likely cause for improved growth. In Lake Erie, the exotic species seemed favored over native species.

Lake Ontario

Alewives dominate the Lake Ontario fish community, but suffer cyclic and catastrophic mortality. Cyclic mortality is found every 3 years in response to cycles in abundance. Catastrophic mortality is found about every 8 years in response to unusually cold winters. Planting large numbers of trout and salmon might increase the carrying capacity for alewives by 1993. Center scientists are using models developed in cooperation with other scientists to test these relations and the effect of an alewife collapse on the fish community.

Potential Effects of Ruffe on Native Fishes in the Great Lakes

The European ruffe is a small perch-like fish that is widely distributed in the rivers and lakes of northern and central Europe. In those areas, the ruffe is held in low esteem because it rarely exceeds 225 mm total length. In addition, the ruffe is prolific and can quickly dominate an area. Recently, the ruffe became established in the Duluth harbor area of Lake Superior. A series of laboratory studies was designed to understand the effect of ruffe on the fish community in the Great Lakes.

The feeding rates of walleye, northern pike, and burbot on ruffe and on their normal diet items, such as yellow perch and soft-rayed fish, were determined in the laboratory. If predators were acclimated on hard-rayed fish (such as yellow perch), they ate ruffe at relatively low rates. Predators showed no preference for either yellow perch or ruffe. If soft-rayed fish (such as lake trout or rainbow trout) were available, predators did not eat ruffe. Predators are unlikely to have any effect on ruffe populations if soft-rayed fish are in the complex of prey species.

Ruffe are a likely competitor with yellow perch. They have similar shapes and sizes, and both species eat large numbers of midge fly (chironomid) larvae. Competitive interactions of ruffe with yellow perch for midge fly larvae were quantified in the laboratory. Ruffe ate more prey and were generally more efficient foragers than yellow perch. These studies suggest a potential for ruffe to reduce yellow perch growth when food is limiting.

Valuable Fish and Wildlife Habitat

Wetlands in the Great Lakes are important to many species of fish and wildlife as spawning, nesting, rearing, and feeding habitat. Proposed changes in regulation of water levels in lakes Ontario and Superior and initiation of regulation in lakes Michigan, Huron, and Erie could alter wetland and aquatic plant communities and affect fish and wildlife habitat. Scientists at the National Fisheries Research Center–Great Lakes studied 17 wetlands along the United States shore of Lake Ontario and 18 wetlands adjacent to Lake Superior to determine the relations between plant communities at different elevations and their associated water-level histories. This information was used to assess potential changes in plant communities if water-level regimes were altered by future changes in regulation schemes.

The results from both lakes showed the greatest diversity in wetland plant communities and faunal habitat at elevations that are flooded each 10 to 20 years and dewatered for 2 successive years between floods. The new regulation scenarios that were evaluated generally proposed to reduce the range of water-level fluctuations and to eliminate year-to-year variability. The predicted results for Lake Ontario wetlands showed that over the projected 90-year study period, the wetland area occupied by the most diverse communities would be reduced substantially by all of the proposed scenarios. In Lake Superior, the most diverse communities would be reduced by some of the scenarios and unaffected by others. The consequences of regulating water levels

Densities of brown trout in Spring Creek, Pennsylvania, were high in the upper and lower segments of the stream and were low in the middle segment. A large silt load in the middle segment appeared responsible for the low density. The silt smothered eggs and reduced reproductive success in the middle segment.

of the other lakes would be similar. Any regulation scenario that alters natural water-level cycles would alter wetland and aquatic plant communities and faunal habitat. Center scientists proposed additional water-level scenarios for each Great Lake that would provide the amplitude and periodicity of water-level fluctuations required to maintain diverse wetland communities.

Trout

Factors Influencing Spatial Distributions of Wild Brown Trout

Spring Creek, a 35-km-long limestone stream in central Pennsylvania, had an unusual distribution of wild brown trout. Densities were high in the upper and lower reaches of the stream and low in the middle reach. Scientists from the Pennsylvania Cooperative Fish and Wildlife Research Unit determined the reasons for the unusual pattern of spatial distribution of trout.

The number of spawning sites (redds) in the creek followed the same pattern as trout densities. Among stream sections, densities of trout redds explained about 50% of the variation in densities of young-of-the-year trout. Redd densities were also positively correlated with densities of adult trout. In stream sections with few redds, survival of trout embryos in redds was low (range: 5–42%), while survival was high (range: 46–80%) in sections with large numbers of redds. Embryo survival was reduced by low concentrations of intragravel dissolved oxygen and high proportions of fine sediment in the redd.

Trout densities in the middle one-third of the stream were low because few sites were available for spawning and because embryo survival was low where trout did spawn. A large silt load in this section contributed to the accumulation of fine material in redds and to reduced availability of spawning sites. Quality of habitat for life stages other than spawning was similar among the three stream sections. Hence, differences in trout densities were attributable to the amount of available spawning habitat and embryo survival. High sediment loads in the stream came from one of three tributaries. Intensive agricultural use, particularly pasture use, of the riparian area was largely responsible for high sediment loads.

Environmental Factors Affect Abundance of Trout Populations

The influence of biological, physical, and water quality characteristics on growth of rainbow trout in 12 northern California high lakes was investigated by scientists with the California Cooperative Fishery Research Unit. Factors that seemed to best explain lake-to-lake variation in trout growth were abundance of aquatic plants (particularly Potamogeton), lake surface area, and alkalinity. A model incorporating these factors for predicting length of age-2 rainbow trout was developed. Recommendations for stocking densities were made after many lakes proved to be overstocked.

A paddlefish from Navigation Pool 8 of the upper Mississippi River exhibits past injuries from a boat-motor propeller. Such scars are commonly observed on large adults, yet the overall impact of navigation traffic on paddlefish populations is unknown. Commercial and recreational navigation traffic is increasing on the upper Mississippi and on many other rivers containing populations of paddlefish. *Photo by S. J. Zigler.*

River Fishes

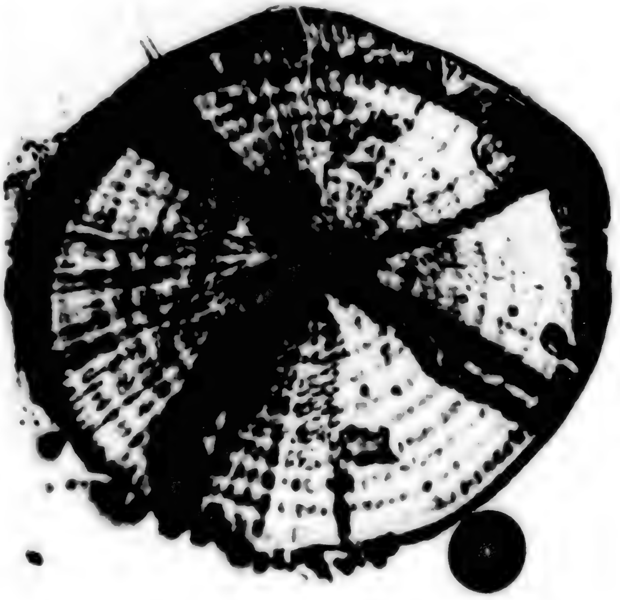
Paddlefish and Lake Sturgeon in the Upper Mississippi River

Biologists with the National Fisheries Research Center–La Crosse worked with Federal and State fishery groups to identify and rank research needed for scientific management of paddlefish and lake sturgeon in the upper Mississippi River. Until the late 1800's, lake sturgeon and paddlefish were abundant in the river. Lake sturgeon were depleted in the early 1900's because of exploitation for caviar, and paddlefish were harvested for caviar when lake sturgeon became scarce. Existing data bases for both species are sparse, and the lack of data hampers management options as habitat loss and continued exploitation threaten local populations of both species.

Both species are now diminished, although self-sustaining populations of lake sturgeon persist in some large rivers and lakes in Wisconsin and Canada. Paddlefish still are found over much of their historic range, and some diminished populations seem stable. Research on lake sturgeon in the upper Mississippi River is needed to identify factors that limit distribution and hamper restoration. Research on paddlefish is needed to assess reproduction and recruitment in impounded rivers in relation to habitat characteristics, navigation traffic, sedimentation, and pollution.

Growth and Mortality of Larval Fishes in the Upper Mississippi River

Biologists at the National Fisheries Research Center–La Crosse compared length and otolith methods for



An otolith from a larval sunfish contains daily growth rings that can be used to accurately estimate the age of the fish. Such age data can be used to quantify the growth and mortality of larval fishes in large rivers. *Photo by S. J. Zigler.*

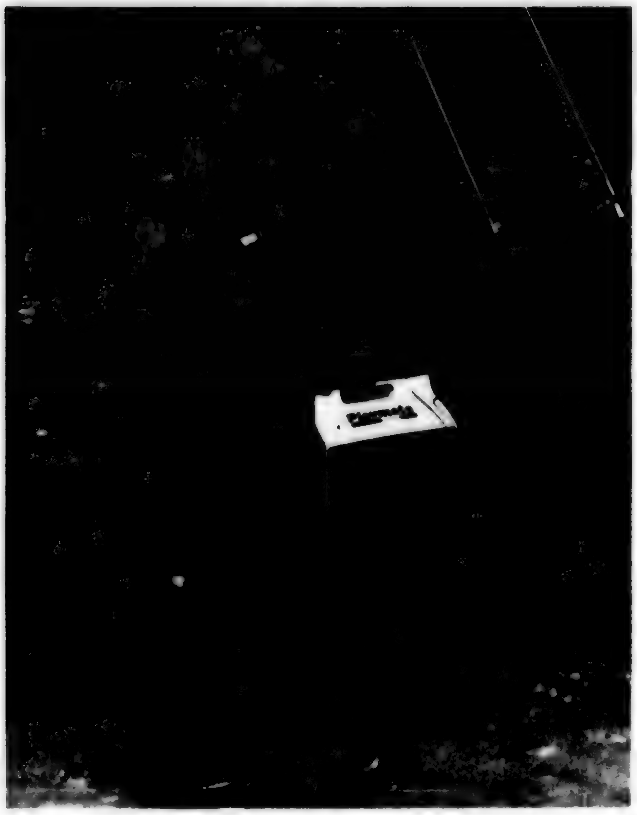
estimating growth and mortality of larval sunfish and freshwater drum in two habitats of the upper Mississippi River. For each taxon, the precision of the estimates of growth and mortality depended on the size of the catch at a given site. For larval sunfish, the otolith method required more laboratory analysis but provided better estimates of growth and mortality than the length-based method. For larval freshwater drum, both methods yielded reliable estimates of growth and mortality. These data and methods will be used to evaluate the effects of human-related fluctuations on larval fishes inhabiting main channel and backwater habitats in the upper Mississippi.

Habitat Affects Distribution of River Fishes

Researchers at the Missouri Cooperative Fish and Wildlife Research Unit found that channel catfish were more abundant along sandbars than dikes in a Lamine River tributary during July 1988–November 1989. Catches of juvenile channel catfish in nets and presence of large fish (>240 mm total length) in the tributary increased during spring, indicating the importance of the tributary as spawning habitat. During warm months (water temperature >20° C) channel catfish were more abundant along sandbars than dikes, while abundances were similar in the two macrohabitats during cool months (October–November). Depth and velocity preferences of channel catfish varied among four size groups examined.

Rehabilitation of Fish Habitat in Riverine Lakes

Biologists at the National Fisheries Research Center–La Crosse worked with the U.S. Army Corps of Engineers, the Minnesota Department of Natural Resources, and Fish and Wildlife Service biologists in North Central Region to evaluate a major habitat-rehabilitation project on the upper Mississippi River. The project involved hydrologic modifications to introduce flow into a series of interconnected backwater lakes that undergo periodic oxygen depletion. The purpose was to define flow rates that most enhance the quality of the lakes as winter habitat for bluegills, black crappies, and other sportfishes. Radio-telemetry studies showed that fish move often within and among the lakes, usually in response to changing concentration of dissolved oxygen. In winter, bluegills and black crappies preferred areas with dissolved oxygen exceeding 1 ppm (1 mg/L), water temperature of 3–4° C, and no discernable current. Flow into one of the lakes from an existing culvert introduced water having ample dissolved oxygen, but with temperatures that were too cold (0.5–1° C) for fish in winter. Fish usually avoided those flows, but used them as refuges when oxygen concentrations in other areas declined below 1 ppm.



Radiotelemetry is being used to evaluate winter habitat of bluegills in a series of backwater lakes in the upper Mississippi River. The amount of habitat suitable for bluegills and other sport fishes is greatly diminished during winter, due to oxygen depletion and low water temperature, two conditions that greatly affect the movement and distribution of bluegills during periods of ice cover. *Photo by B. L. Johnson.*

Fish Guilds in Large Rivers

Biologists at the National Fisheries Research Center–La Crosse assessed factors that determine the distribution of minnows and juvenile game fishes in shallow-water habitats of the upper Mississippi River and the Tallapoosa River, a medium-size river in Alabama. Rooted aquatic plants were the primary source of cover in the upper Mississippi, whereas fallen trees were the primary cover in the Tallapoosa River. The principal fish species differed between the two rivers, but the fish communities were structurally similar. Fish communities varied along a gradient of habitat complexity–ranging from open, fast-water sites to areas with slow current and abundant cover. A common set of habitat factors may control the structure of riverine fish communities, even in rivers that differ widely in size and habitat characteristics.

Potential Effect of Global Warming on South Appalachian Fishes

Researchers at the National Fisheries Research Center–Gainesville studied the potential effects of global climate change on selected species of southern Appalachian fishes. The area selected for study encompassed headwater tributaries of the Coosa River drainage in northern Georgia and Alabama. This area drained the southern terminus of the Blue Ridge and Piedmont formations, while the coolest montane streams and springs are found in the southeast. The targeted species included cold-adapted endemic sculpins, darters, and minnows with some forms limited in distribution to springs, and others more widespread in stream habitats. Several of the species were listed or under review for status as threatened or endangered because of declining populations in limited or perturbed habitats.

Laboratory studies were conducted to compare the thermal requirements of those species confined to thermally stable cold springs (<15° C) with closely related species from thermally fluctuating streams. Lethal maximum and preferred temperatures were determined for the selected species to establish baseline data for assessing the extent to which populations may withstand potential environmental warming. Various combinations of acclimation sequences on fish removed during seasonal extremes were used to isolate genetic components of thermal adaptation from phenotypic plasticity.

Historical distributions of the targeted species were delineated from museum collections, and field surveys were conducted to establish present ranges and collect ecological data. The distributions of the fishes were analyzed by using geographic information system (GIS) technology for possible chronological patterns associated with historical anthropogenic changes in watersheds, geological and hydrological features, and ecological characteristics. Results from the thermal biology studies will be combined with distributional data to establish models of physiological and ecological requirements. These models project loss of available habitat if climatic change increases temperatures of the aquatic systems inhabited by the target species.

Effects of Stocking Threadfin Shad on Young-of-year Crappie, Bluegill, and Largemouth Bass

Scientists at the Ohio Cooperative Fish and Wildlife Research Unit stocked threadfin shad in two Ohio lakes in 1988 and 1989 to assess growth of resident bluegill, crappie, and largemouth bass. Stocking shad did not increase numbers of young-of-year (YOY) of the three species of sportfishes. In fact, abundances of YOY fishes of all three species declined in the post-shad years. Further, growth of YOY largemouth bass remained constant or declined commensurate with the reduced availability of YOY bluegill as prey. The interaction between shad and zooplankton was critically important to shad presence as forage, especially in less productive systems where zooplankton populations were likely to be driven to low abundance by shad. Shad are unlikely to benefit communities dominated by bluegill, crappie, and largemouth bass because of their omnivorous feeding, high fecundity, and rapid growth.

Diets Affect Growth of Largemouth Bass

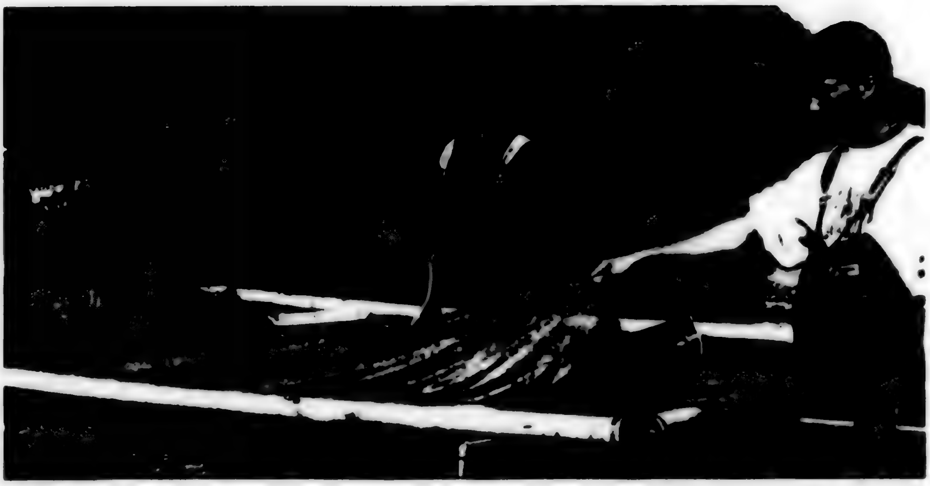
The Missouri Cooperative Fish and Wildlife Research Unit staff found that caloric growth rates of largemouth bass from two Missouri reservoir populations differed when they were fed equivalent specific daily rations bracketing maintenance levels. A significant difference in the growth response was observed between the populations, indicating that the assumption of homogenous growth responses to given levels of caloric intake (common in applied fish energetics studies) may be risky. A similar evaluation dealing with stomach evacuation rates for the two populations indicated this variable to be more consistent across populations.

Food Limits Shad Larvae Survival

Direct estimation of daily ration and energy intake for larval gizzard shad was completed during a 2-year study by Missouri Unit scientists in Lake Pomme de Terre. In both years, energy intake by shad larvae fell below maintenance requirements because shad larval densities peaked and declined precipitously. Food limitation played a direct role in determining the numbers of shad larvae that survived to the juvenile stage each year. Juvenile shad served as prey for sportfishes and were important to sportfish survival and growth.

Innovative Methods for Sampling Young Fishes

Biologists at the National Fisheries Research Center–La Crosse tested new methods for sampling young fishes in riverine habitats. Many large rivers contained shallow, heavily vegetated backwaters that were highly productive, yet difficult to sample. Tests in both vegetated and nonvegetated habitats showed that pop nets and drop nets were efficient for quantitative sampling of juvenile fishes in a known area of habitat. Another gear, the electrofishing frame, was not effective in turbid or heavily vegetated



Pop nets are being used to quantify the abundance of juvenile fishes in vegetated backwaters along the upper Mississippi River. In many habitats, such as the heavily vegetated backwater lake shown here, fishes cannot be sampled with conventional sampling gear. *Photo by R. J. Kennedy.*

areas because of difficulty in locating stunned fish.

The zonation of larval fishes in backwater habitats was revealed by nocturnal sampling with light traps that contained chemical light sticks and a slotted funnel trapping system to attract and trap larval fish. In a backwater lake, larval gizzard shad and minnows used open-water areas adjacent to vegetation beds. In contrast, larval sunfishes were abundant throughout dense beds of both submergent and emergent vegetation, but were rare in areas lacking rooted vegetation. Data obtained with these sampling gears were used to evaluate the importance of various habitats in the production of key sport and commercial fishes.

Use of a Biomarker to Determine Tumor Presence

The Missouri Cooperative Fish and Wildlife Research Unit biologists studied the potential of serum N-acetylneuraminic acid (NANA) as a biomarker of tumor presence in wild fish. Variation of serum NANA was determined by analyzing six species: brown bullheads, channel catfish, brook trout, Atlantic salmon, bluegill, and smallmouth bass. Brown bullheads exhibited tumor formation in some geographic areas having heavy industrial pollution. Bullheads were analyzed from four sites: two with high tumor incidence and two with healthy populations. Serum NANA concentrations were significantly different between some populations. Serum NANA concentrations may be indicators of stress, but were not biomarkers of tumor presence in brown bullheads.

Exotic Fishes

Nonindigenous Species Data Base

The National Fisheries Research Center–Gainesville continued to monitor the status and distribution of exotic fishes known or suspected to degrade fisheries resources. Information gathered since 1979 was stored in a computerized, national repository data base accessible to all State, Federal, and private sectors for use in preserving and enhancing the Nation's resources. The close coordination and exchange of information between Fish and Wildlife Service personnel and other agencies and individuals resulted in the cataloging of 47 exotic fishes established in United States waters and an additional 63 exotic fishes found but not known to be established.

The Gainesville Center undertook an initiative with the outbreak of zebra mussels in the eastern half of the country. State-of-the-art computer technologies were applied to the "bio-Geographic" problems associated with all nonindigenous aquatic species, including exotic fish. This bio-geographic analysis system stored and analyzed biological and geographic information for use by researchers and managers in understanding and controlling nuisance species. Today, 135 species are described within more than 1,800 records stored on this system. Information is constantly provided to Federal, State, and private entities for monitoring, analysis, and management.

Spread of Exotic Fish Species

Field surveys by scientists from the National Fisheries Research Center–Gainesville determined the distribution of exotic fishes in several geographic regions of the United States and the presence of another exotic fish, the yellowbelly cichlid. This species, formerly established in Florida, was believed eradicated, but recent findings suggest firm establishment. Survey data also indicated several other aquarium fishes, including black acara and blackchin tilapia, increased their range in Florida. The Center also monitored the spread of the rudd, a European minnow

Personnel at the National Fisheries Center–La Crosse found the first zebra mussel reported from the upper Mississippi River during field collections of native mussels. The zebra mussel was attached to a native pigtoe mussel. *Photo by L. L. Marking.*

and a popular bait fish. According to reports from State and Federal agency biologists, the rudd seemed on its way to becoming established in several areas of the central and eastern United States.

Controlling Zebra Mussels in Lake Erie

The zebra mussel spread rapidly across the Great Lakes region and has been found recently as far south as Alabama. Zebra mussels tolerate and reproduce in a wide range of environmental conditions, characteristics that enable them to colonize rapidly. Once adult mussels colonize, eradication is impossible without the use of toxic chemicals such as chlorine or rotenone. While chemical use is acceptable for power plant coolant systems, it is not acceptable for natural ecosystems because all biota would be killed. No specific chemical is available that selectively kills only zebra mussels.

Scientists at the National Fisheries Research Center–Great Lakes studied the life cycle of zebra mussels to determine biological control methods that might reduce zebra mussel numbers. In Europe, predation by fish and ducks is considered the main reason mussel numbers remain low. An option studied was the potential of native fish as predators. A number of different fishes, especially large freshwater drum, readily eat zebra mussels, but fish predation did not reduce mussel populations substantially.

Interruption of the mussel lifecycle at the larval stage offered an additional area for non-chemical control. The planktonic larvae, or veligers, seemed more vulnerable than adult mussels. Veligers are intolerant of environmental changes, and mortality rates of more than 99% are frequent. The highest veliger mortality rates occur when larvae settle out of the water column onto the bottom of the lake or river. Causes of the high mortality at this stage are under investigation.

Substitute Control for Zebra Mussel

In early 1991, mussels were found in the Illinois River and by late summer of that year were found in the upper Mississippi River from St. Louis, Missouri, upstream to La Crosse, Wisconsin. Industries, municipalities, and commercial mussel fishermen on rivers fear that economic and biologic losses similar to those of the Great Lakes will rapidly develop in large river systems. Researchers at the National Fisheries Research Center–La Crosse are working in cooperation with researchers at Ohio State University to evaluate alternative chemicals for control of zebra mussels in industrial and municipal settings. Promising candidate chemicals are screened in standard toxicity tests using zebra mussels as well as nontarget organisms including unionoid mussels, sphaeroid clams, and fish species. Screening of 20 chemicals was completed, and results indicate that Bayluscide and TFM, both registered for use in sea lamprey control, were more toxic to zebra mussels than to unionid mussels, sphaeroid clams, and some fish species. Several commercially available molluscicides were not toxic to mollusks during short duration periods but were highly toxic to fish. Candidate chemicals will be further tested under varying experimental conditions and evaluated on the basis of their toxicity, cost, ease of application, and environmental safety.

Contaminants

Industrial Contaminants and Acidic Precipitation

Researchers from the National Fisheries Contaminant Research Center and the Missouri Cooperative Fish and Wildlife Research Unit simulated acidic episodes likely to be found during snowmelt and summer storms to determine the sensitivity of native western salmonids to acidification. Golden trout were as sensitive or more sensitive than most eastern salmonids to conditions likely to be found during episodic acidification events. Depending on site-specific water quality characteristics, significant mortality may be found among golden trout when the pH of surface waters falls below 5.0 in the absence of aluminum, or when pH reaches 5.5 in the presence of aluminum concentrations as low as 100 parts per billion (ppb). Behavioral impairments at sublethal levels of acid and aluminum would limit the ability of early life stage fish to maintain position in the water column, to forage efficiently, and to avoid predation.

Deleterious behavioral impairments could be found among early life stage golden trout at aluminum concentrations as low as 50 ppb and at a pH as high as 5.5. During periods of increased flow from precipitation, many headwater streams in Pennsylvania experienced pH depressions and an increase in dissolved aluminum. These conditions, termed episodic acidification, may adversely affect survival and development of eggs and larvae of brook trout.

Scientists at the Pennsylvania Cooperative Fish and Wildlife Research Unit compared the survival of early life stages of brook trout among headwater streams that varied in degree of episode severity. Brook trout spawning sites (redds) were located, and water quality and substrate suitability were measured at each redd. Embryo survival was determined before larvae emerged from the redds, and survival of larvae on each stream was measured. In both studies, embryo survival (range: 8% to 82%) decreased as concentrations of inorganic monomeric aluminum (range: 0 to 400 ppb) increased. In addition, the rate of larval development was slowest in the most acidified stream. Episodic acidification could cause declines in brook trout populations by reducing survival of early life stages.

Biologists at National Fisheries Contaminant Research Center identified atmospheric deposition as a major source of mercury contamination to both aquatic and terrestrial systems. Analysis of mercury content of precipitation, soil, stream water, and fish from an experimental watershed in Maine revealed that precipitation was the major source of mercury to the watershed. Precipitation accounted for all of the mercury accumulated in brook trout in 1 year. The source of mercury in precipitation was unknown; however, analyses of mercury in peat bogs and lake sediments indicated present-day deposition 2–10 times higher than in pre-industrial time (19th century). Agriculture, mining, industrial processes, combustion of fossil fuels, and incineration of refuse are believed to be the cause of increased depositional rates. Regions receiving acid precipitation may also receive high amounts of mercury; acidification of soil and

California Fish and Game biologist collect golden trout eggs for a cooperative study with the Fish and Wildlife Service and the U.S. Forest Service on acid deposition in the Sierra Nevada.

surface waters may facilitate the conversion of mercury into methyl mercury, the toxic form accumulated by fish.

Habitat Restored by Removal of a Tide Gate

Individuals from Research and Development teamed up with the Southeast Region operational staff to successfully reverse a U.S. Army Corps of Engineers project in the Savannah River Basin. The result was restoration of valuable fish and wildlife habitat.

In 1977, the U.S. Army Corps of Engineers installed a tide gate on the lower Savannah River drainage. Fish and Wildlife Service research studies by the National Wetlands Research Center–Lafayette indicated that operation of the tide gate increased salinity in the river, thus reducing the freshwater supply for the management of marshes on the Savannah National Wildlife Refuge. More than 1,619 ha (4,000 acres, about 74%) of valuable tidal fresh wetland on the refuge had been converted to saline or brackish marsh. In addition, the altered salinity regimes in the Savannah River reduced productive habitat for striped bass spawning. Studies confirmed that tide gate operation caused the rapid flushing of striped bass eggs into saline waters. The saline waters were toxic to the eggs and resulted in a 95% reduction in striped bass spawning success in the river compared to the late 1970's. Based on results from this research, the U.S. Army Corps of Engineers ceased operating the tide gate in 1991. This immediately reduced the salt water intrusion upriver and allowed initiation of recovery of the marshes on the Refuge.

Polychlorinated Biphenyls Still Added to Upper Mississippi River

In other studies, extensive reaches of the upper Mississippi River remain contaminated with polychlorinated biphenyls (PCB's), even though the use of PCB's has been restricted and their production banned for several years. Iowa, Minnesota, and Wisconsin have issued fish-consumption advisories (2 parts per million (ppm) in fish) for several species from the contaminated portions of the river. Mayflies, an important food organism for fish and wildlife, were collected from different locations in the upper Mississippi River and analyzed to assess the spatial variation in bioavailability of PCB's. Total PCB's in mayflies ranged from 0.21 to 4.1 ppm. Highest concentrations were found in mayflies in pools 2 through 6 (adjacent to and extending 177 km (110 miles) downstream from the Minneapolis–St Paul) and at Pool 15 (below the Quad Cities on the Iowa–Illinois border). Samples from these sites contained a larger number of low molecular weight congeners that persist for only a short time in the environment. The relative abundance of low molecular weight PCB congeners suggested a recent introduction of PCB's at these locations.

Water quality monitoring by State and Federal agencies further supported the continued introduction of PCB's into the river in intermittent run-off from urban and rural non-point sources as well as industrial point sources. Mayflies proved useful as in-situ indicators of PCB contamination in aquatic habitats.

Mussels Decline in Upper Mississippi River

The mussel fauna of the upper Mississippi River has been declining in density and diversity, perhaps because of contaminants in water and sediment. Scientists at the National Fisheries Research Center–La Crosse assessed the toxicity of the metal cadmium on the pocketbook mussel *Lampsilis ventricosa*. Acute toxicity tests with early life stages indicated that young juvenile mussels (less than 7 days of age) were more sensitive to sublethal concentrations of cadmium than older juveniles (14 days) and younger larval stages (termed glochidia). Shell growth was reduced in juveniles exposed for 7 days to 10 ppb of cadmium in water. Respiration rate, which was significantly diminished in adult pocketbook mussels exposed to 30 ppb of cadmium, was the most sensitive and least variable physiological indicator of sublethal cadmium stress in adult pocketbook mussels. Rates of food clearance and ammonia excretion were also decreased by exposure to cadmium. Exposure to cadmium may adversely affect mussels in large river systems.

Agricultural Irrigation Drain Water

Elevated salinity and trace elements in water, a result of irrigating arid agricultural areas, have been identified at numerous sites throughout the western United States and are a threat to fish and wildlife resources. Biologists at National Fisheries Contaminant Research Center conducted both on-site and laboratory assessments to evaluate the toxicity of surface and ground waters at Stillwater Wildlife Management Area. Toxicity tests using both freshwater and saltwater organisms were con-

Biologist installs device to collect 24-h composite samples from an irrigation drainwater canal that supplied water to Stillwater National Wildlife Area, Nevada.

ducted with surface waters collected daily. Effluent in several of the drains was determined to be moderately to very toxic to both freshwater and saltwater organisms. The toxicity was related to the presence of arsenic, boron, lithium, and molybdenum. Although none of these individual trace elements was present at acutely lethal concentrations, mortality was a result of their combined concentrations and was positively correlated with the conductivity of the water.

The ionic composition of the water, without addition of the trace elements, was acutely toxic to saltwater organisms in a salinity range that should have been acceptable for survival. Experimental waters reconstituted to approximate the abnormal ratios of major salts in the drainwater (calcium, magnesium, sodium, potassium, alkalinity, sulfate, and chloride) were toxic. The addition of the trace element concentrations, similar to that present in Stillwater drains, to the reconstituted water increased the observed toxicity. Furthermore, all but one of the groundwaters sampled from the Stillwater Wildlife Management Area were toxic to fresh- and saltwater organisms. These findings indicated that some surface waters at the Stillwater Wildlife Management Area were a hazard to aquatic organisms and that sources of fresh water were needed for dilution or replacement. Conductivity may be used to assess the acceptability of water for the Stillwater Wildlife Management Area because of the strong relation with mortality. Water from certain drains is no longer accepted by the Refuge, and gradual improvement in water quality is anticipated.

Bioassessment Technologies

Researchers at the National Wetlands Research Center–Lafayette, Louisiana, using GIS, compiled a series of data bases containing details on metal contamination and pollution sources in Galveston Bay, Texas. Researchers used these data bases and ARC/INFO GIS software to create a series of maps with various overlays. This technology was recently used in a cooperative study with the Galveston Bay National Estuary Program.

The Fish and Wildlife Service's GIS capabilities were used to store, manipulate, analyze, and display both historical data on Galveston Bay and data created as a result of the study. The historical data included layers such as the benthic community data, biological resources, sediment chemistry, and contaminant input sites. Data generated included information regarding the levels of various contaminants. The GIS provided an overview of the sediment quality in the bay and the identity of areas seriously affected by contaminants. A GIS model is being developed to assess the potential effects of contaminants to fish and wildlife resources.

A study by biologists at the National Fisheries Contaminant Research Center and the Iowa Cooperative Fish and Wildlife Research Unit evaluated free cadmium and the protein metallothionein (MT) in fish liver as indicators of exposure to both aqueous cadmium and sediment-associated cadmium, and assessed the bioavailability to fish of cadmium in resuspended river sediment. Mobilization of cadmium from sediments into the water column is found during resuspension, and sediment-associated cadmium is biologically available. Free cadmium concentration in bluegill liver was the most sensitive indicator of aqueous cadmium exposure. In contrast, whole-body cadmium concentrations in bluegills were more sensitive indicators of cadmium exposure from sediment than either free cadmium or MT concentration.

Bioavailability Indicator

The so-called "soft" pesticides that replaced organochlorines do not generally bioaccumulate, a characteristic that has lessened the threat of chemical exposure to fish and wildlife through the food chain. Because these and other classes of chemicals do not bioaccumulate, simply collecting and analyzing organisms of concern will not adequately document chemical exposure and subsequent toxicity of the soft pesticides. This shortcoming of current monitoring methods requires new strategies and technologies. One such approach, used in monitoring exposure in humans, is the passive integrative monitor (i.e., dosimeter) that has been widely accepted for determining occupational chemical exposure of workers to organic chemicals in air. Until recently, no such integrative exposure tools existed for fish and wildlife resources.

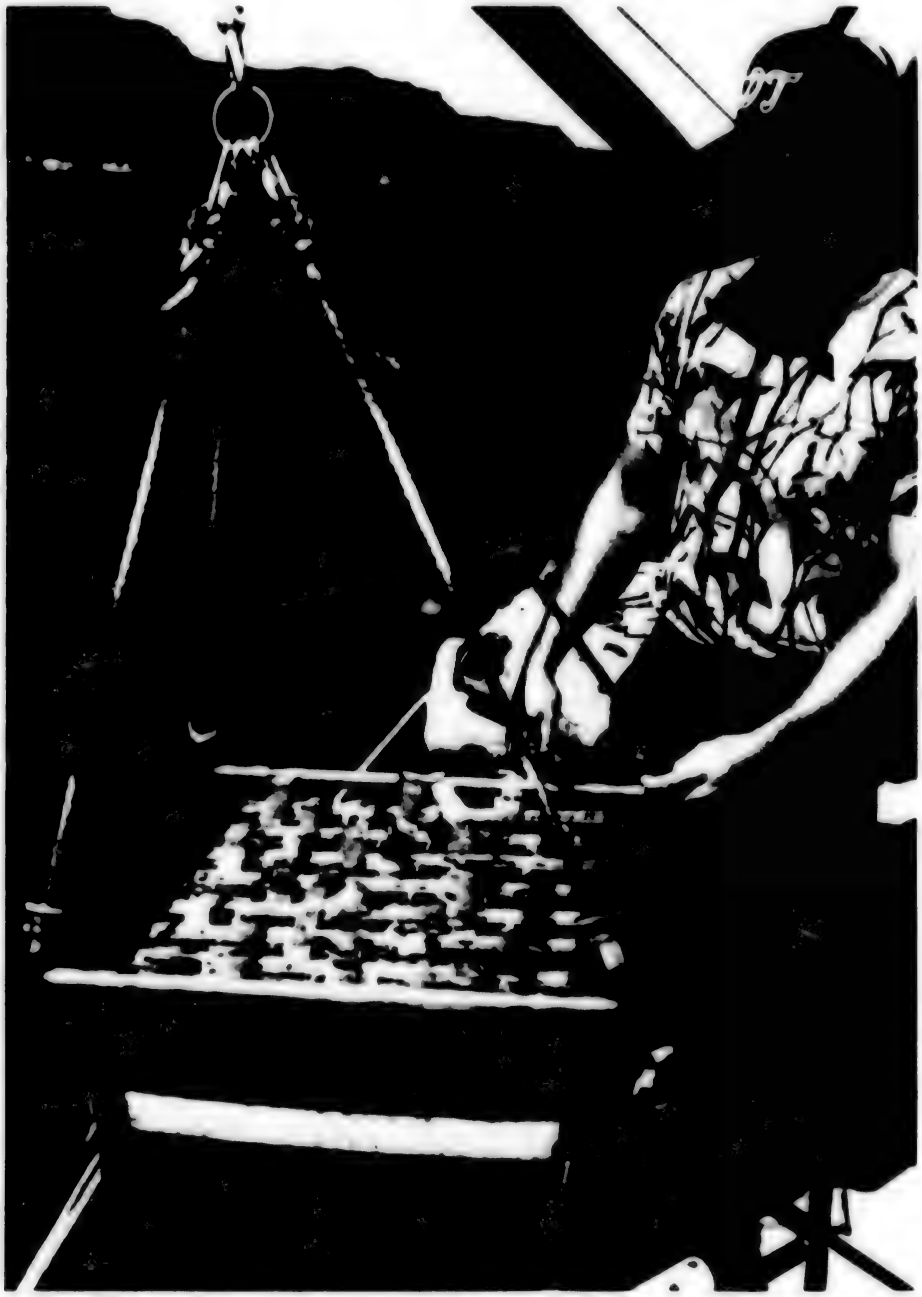
A lipid-containing semipermeable membrane device (SPMD), developed and patented by researchers at the National Fisheries Contaminant Research Center, is functionally similar to occupational dosimeters. The SPMD, which consists of a thin film of lipid sandwiched between two layers of polyethylene or other similar plastic membrane, can be deployed for extended periods in either air or water. The device mimics the bioconcentration of contaminants by organisms, and seems to be an effective tool for determining the quality of fish and wildlife habitat relative to organic contaminants. This technology represents a significant advance in the ability to uniformly assess fish and wildlife exposure to contaminants and could be broadly used in the Service's contaminant monitoring program.

Mathematical models were developed for estimating the average concentrations of contaminants in water from their concentrations in exposed SPMD's. Flow-through laboratory exposure studies with a PCB and a polyaromatic hydrocarbon (PAH) showed that a single SPMD, containing only 0.91 g of lipid, daily extracts PCB's from about 5 L of water and PAH's from about 7 L of water. The SPMD technology is being used in collaboration with the U.S. Geological Survey in the upper Mississippi River as a part of new technology development within the U.S. Fish and Wildlife Service's Biomonitoring of Environmental Status Trend (BEST) Program.

Technological Development and Assessment of Contaminated Sediments

Several techniques were evaluated for assessing the genotoxic potential of the complex chemical mixtures found in aquatic sediments. Hydrophobic contaminants such as PCB's, PAH's from fossil fuel production and use, pesticides, and dioxins accumulate in sediments. In addition to their potential for toxicity to aquatic organisms, some sediment contaminants are genotoxic and a suspected cause of tumors found in wild fishes from highly polluted areas. In recent studies by scientists at National Fisheries Contaminant Research Center, organic extracts of sediments from selected Great Lakes tributaries were screened for genotoxic potential by using the well-established Ames assay and the more recently developed Mutatox photobacterial assay. Both assays identified genotoxins in the sediment samples. Cytotoxicity of the samples masked genotoxic potential in the standard Ames assay and required modification of sample preparation and test procedures. The Mutatox assay was less affected by cytotoxicity, compared favorably in terms of sensitivity, and required less time, equipment, and expense to conduct than the Ames assay. These tests for genotoxicity of sediment extracts added an important dimension to the assessment of aquatic pollution. Of the two techniques used in this project, the Mutatox assay may be more amenable to large-scale monitoring programs.

Scientists at the National Fisheries Research Center–La Crosse, working cooperatively with the University of Wisconsin–La Crosse River Studies Center, examined the mercury content of surficial sediments in northern Wisconsin lakes. The mercury influx to the six seepage lakes, which lacked inflowing streams and received negligible runoff, was almost totally from direct precipitation onto the lakes. Whole-lake burdens of mercury in the top 5 cm of sediment, and estimates of the maximum pool of sedimentary mercury that was potentially available to biota, ranged from 45 to 149 g in the six lakes. These sedimentary pools greatly exceeded the inventories of the metal in all other lake components, and the release of mercury from the sediments could significantly increase the accumulation of the metal in lake biota. Whole-lake burdens of mercury, normalized for



Biologists placed semipermeable membrane devices (SPMD's) in the upper Mississippi River to determine the availability of PCB's to aquatic organisms. SPMD's were sampled along a time series to evaluate rate of PCB accumulation under field conditions; samples of channel catfish were collected from in-situ cages along the same time series for comparison.

lake area, varied almost five-fold among lakes (from 1.65 to 7.84 g/ha), were positively correlated with burdens of organic matter in sediment, and were inversely correlated with lake pH. It is believed that the observed variation in whole-lake burdens of mercury was partly because of variation among lakes in the pH-related efflux of gaseous mercury (Hg°) from the water column to the atmosphere.

Fish Diseases

Non-lethal Alternatives for Fish Health Inspections and Early Detection of Fish Pathogens

Health inspections provide valuable information about the presence of pathogens within populations of fish. Current inspection procedures require samples from internal organs, necessitating sacrifice of the fish. Use of tissues that could be obtained without sacrificing the fish was investigated. Researchers at the National Fish Health Research Laboratory reasoned that mucus from the skin of fishes would be useful material for non-lethal sampling for the presence of fish pathogens because the mucus is considered to be the first line of defense against infection. One hundred lake trout from a population undergoing an epizootic of furunculosis, caused by *Aeromonas salmonicida*, were used to compare results from mucus and kidney samples. The bacterium was isolated from the mucus of 63 fish and from the kidney of only 6 fish. In a population of Atlantic salmon showing reduced feeding and abnormal behavior but no clinical signs of disease, 17 of 27 fish examined had *A. salmonicida* in the mucus but only 2 kidney samples were positive. Several non-lethal sampling methods were investigated for suitability in determining the prevalence of virus causing infectious pancreatic necrosis, a serious disease of young salmonid fishes. Comparison of results from lethal sampling of internal organs with non-lethal samples of ovarian fluid, blood, abdominal cavity washings, mucus, fin tissue, gill tissue, and feces indicated ovarian fluid samples were equally as good as lethal samples. Unfortunately, ovarian fluid is only available at spawning time, and it is often desirable to test fish at other times. Blood plasma was unsuitable for use, and white blood cell samples gave inconsistent results.

Virus was isolated from mucus more often than from other external tissues but only in small quantities. Mucus may not be adequate as the sole source of samples for fish health assessment, but it does provide an additional non-lethal diagnostic opportunity.

Molecular Methods for Study of Fish Viruses

Scientists at National Fisheries Research Center–Seattle used T1 ribonuclease fingerprinting and RNA sequence analysis to learn more about the evolution and genetic diversity of IHNV and VHSV isolates. A unique "fingerprint" pattern for each virus was generated by separating digested fragments of viral genetic material in two dimensions. The IHNV fingerprints were compared to determine if North American IHNV strains were related to the geographic area from which they came, to the host species, or to biological features (e.g., virulence). A series of IHNV isolates from three locations collected at intervals over a number of years was also examined. Results showed that the virus changed over time, even in the same river system, but changes were greater with increasing geographic isolation.

The fingerprinting technique was applied to isolates of North American and European VHSV to determine their relations. The North American and European strains formed two distinct groups suggesting they have evolved in isolation for a considerable time.

DNA Probes for the Rapid Detection and Identification of Fish Viruses

Workers at National Fisheries Research Center–Seattle developed a highly sensitive method for rapid detection of IHNV based on a DNA probe and amplification by the polymerase chain reaction (PCR). These techniques were applied to VHSV as well. A conserved unique DNA sequence was discovered in the nucleoprotein gene in each of a North American and a European VHSV strain. Two DNA probes were synthesized that would bind specifically with these sequences. The European VHSV probe can recognize all strains of the virus while the North American probe recognizes only the eight North American isolates. This gives fish health workers a method for differentiating the highly virulent European strains from the less virulent isolates from the west coast of the United States.

Research staff at the National Fish Health Research Laboratory have developed a rapid and highly sensitive assay using DNA probes and amplification by the polymerase chain reaction assay for the detection and identification of IPNV, IHNV, and VHSV, simultaneously. Comparisons were made between PCR, dot-blot enzyme-linked immunosorbent assay (ELISA), and infectivity assays using cell culture-grown virus. The PCR assay was more sensitive than dot-blot ELISA, but less sensitive than cell culture assay.

Viral Hemorrhagic Septicemia Virus from North America Less Virulent

With the isolation of viral hemorrhagic septicemia virus from fish in North America, researchers questioned whether these strains were as highly pathogenic for salmon and trout as were their European counterparts that cause massive mortality in trout farms. Workers at the National Fisheries Research Center–Seattle conducted fish challenge tests under controlled conditions with VHS virus isolates from the State of Washington. Chinook, coho, pink, chum, sockeye, and Atlantic salmon, and rainbow trout and steelhead were tested. North American VHSV strains were much less virulent than the European strains. This information and the recent recovery of VHS virus from Pacific cod in Alaska suggested that although North American strains of VHSV share a high level of antigenic relatedness with European strains, they are of independent origin and that VHSV may be always present within marine fishes in the Pacific Ocean.

Isolation of the Herpesvirus in Lake Trout

Sporadic incidents of mass mortality involving young and yearling lake trout were found at Federal and State fish hatcheries in the upper Great Lakes Basin. An infectious disease caused by a herpesvirus was responsible for the losses. The virus was most probably introduced by infected wild broodstock. In an attempt to eradicate the virus, broodstock and production lots of lake trout were destroyed and hatcheries disinfected. The loss of these fish stocks and hatchery production capabilities compromised the effectiveness of lake trout restoration programs. Captive lake trout broodstocks are being developed, but wild broodstock are still needed because of the scarcity of various strains of fish. Unfortunately, wild broodstock may carry the virus, and currently, virus infection can be accurately diagnosed only during disease outbreaks. Because no cell culture system has been found that supports virus replication, lack of sufficient quantities of virus for study has been a major obstacle to development of techniques to detect the virus in apparently healthy fish.

Observation that the virus was easily transmitted by contaminated water led to development of a procedure for recovering the herpesvirus from water by ultrafiltration. Contaminated water from an infected fish population is passed through filters of progressively finer porosity to isolate and concentrate the virus. The system is effective, and virus yields have been sufficient to begin developing diagnostic methods that are specific for the detection and identification of lake trout herpesvirus genetic material and viral structural components.

Antimicrobial Resistance in Edwardsiella ictaluri *Could be Transferred from Warm-blooded Domestic Animals*

Enteric septicemia of catfish (ESC), caused by *Edwardsiella ictaluri*, is a major cause of mortality among cultured channel catfish. Romet® (sulfadimethoxine and ormetoprim) is used to control this disease; however, increasing numbers of *E. ictaluri* strains are becoming resistant to Romet®. Studies by scientists at National Fisheries Health Research Laboratory have shown the resistance is encoded on an R-plasmid, a segment of extrachromosomal DNA. This plasmid also conferred resistance to tetracycline and oxytetracycline. Strains of *Escherichia coli*, a common intestinal bacterium of warm-blooded animals, can carry this R-plasmid and transmit it to antimicrobial sensitive strains of *E. ictaluri* by single-step conjugation. Strains of *E. coli* carrying such plasmids can enter the aquatic environment from barnyard or stockyard runoff. These findings present another argument against overuse of antimicrobials in domestic animals.

Sarafloxacin Hydrochloride—A New Therapeutant

Sarafloxacin hydrochloride (Sarafin®), a product of Abbott Laboratories in North Chicago, Illinois, is the first of a new class of therapeutants, the arylfluoroquinolones, that is being promoted specifically for the treatment of bacterial diseases of fish. In field trials, Sarafin® has proven particularly effective in treating enteric septicemia of catfish, a major disease of channel catfish caused by the Gram-negative bacterium *Edwardsiella ictaluri*. The bactericidal activity of sarafloxacin hydrochloride is based on the inhibition of bacterial DNA-gyrase. Abbott Laboratories hopes to secure FDA registration approval of Sarafin® to treat ESC in channel catfish sometime in 1993.

One major FDA requirement for registration is that studies be conducted to define the distribution, metabolism, and elimination of sarafloxacin hydrochloride in treated channel catfish. The National Fisheries Research Center–La Crosse has worked with the Chemical and Agricultural Products Division of Abbott Laboratories to develop the required information. Total residue depletion and metabolism studies were conducted in juvenile channel catfish that had been dosed orally with [^{14}C]sarafloxacin hydrochloride for

Channel catfish showing the "hole-in-the-head" lesion caused by *Edwardsiella ictaluri.*

5 consecutive days to document tissue distribution and elimination of all radioactive residues. Additionally, skinless fillet tissues were sampled and analyzed for sarafloxacin hydrochloride and suspected metabolites by high performance liquid chromatography (HPLC) using fluorescence detection and inline radiochemical monitoring.

Sarafloxacin residues were eliminated rapidly after dosing. Sarafloxacin hydrochloride was the only residue that was identified in the fillet tissues when samples were analyzed by HPLC; no metabolites were detected. Six hours after dosing, 23.5% of the dose was recovered but by 24 h only 4.8% of the dose was recovered. Only 0.2% was recovered after 240 h. During the first 24 h, the sarafloxacin dose was concentrated in the gastrointestinal tract. Thereafter, greatest proportions of the dose were associated with the skin, head, and skeleton. Measurable concentrations of sarafloxacin were found in all tissues at the last sampling time. Highest concentrations were found in the soft organs of clearance such as liver and kidney. Concentrations of sarafloxacin hydrochloride in the edible fillet were consistently among the lowest of all tissues obtained at each sample time.

The effectiveness of the therapeutant against ESC and the relatively rapid clearance of the material from the tissues suggest that sarafloxacin hydrochloride will be an important therapeutic tool for catfish culturists.

Fish Immunology and Diet

Scientists at the Georgia Cooperative Fish and Wildlife Research Unit showed vaccination of channel catfish against *E. ictaluri* enhanced the ability of macrophages to produce intracellular superoxide anion after phagocytosis of live bacteria. This ability was also positively correlated with oil and vitamin E content in the diet. Immunostimulants, such as levamisole, administered alone, increased the fish's basic non-specific antigenic response. Increased enzyme activity in neutrophils and increased phagocytosis resulted when fish were exposed to pathogens. When levamisole was administered with a vaccine, greater antibody levels and more antibody-producing cells were found than when the vaccine was administered alone. Feeding a carefully formulated diet when administering vaccines has great potential to further reduce loss of channel catfish to enteric septicemia.

Research to Identify Effective Antifungal Agents

Malachite green was used widely to control fungal infections in fish; however, its cancer-causing poten-

Male channel catfish (*right*) grow significantly faster than females. The technique developed at the Southeastern Fish Cultural Laboratory will allow fish producers to genetically produce all male fingerlings. *Photo by L. Torrens.*

tial has limited its use and has raised the priority of developing a replacement antifungal drug. In 1989, the Bonneville Power Administration funded a project by the U.S. Fish and Wildlife Service to identify candidate antifungal agents. The research was conducted at the National Fisheries Research Center–La Crosse and at the Oregon Cooperative Fishery Research Unit in Corvallis. The studies focused on three life stages: eggs and juveniles (La Crosse) and adults (Corvallis). Sixteen compounds were tested in vivo and the following controlled the fungus on eggs without adverse effects: malachite green, amorolfine, glutaraldehyde, iodine, formalin, and sodium chloride. Malachite green and formalin were effective against fungal infections in adults, whereas iodine was not. The prognosis is good for finding effective candidate compounds, especially for the treatment of salmoid eggs and juveniles.

Fish Husbandry

Development of culture technology is vital to the increasing demand by fishery managers in the United States for viable fish populations. Fish and Wildlife Service scientists conduct research on new and improved husbandry techniques, develop high quality, low-cost fish feeds, and work to improve water quality, which is critical to fish health and survival. Restoration is enhanced through development of methods that promote growth, health, and fitness of fish in hatcheries.

Nutrition and Feeding

Nutrition, feeds, and feeding continued to be critical in the restoration of nationally important wild populations of fishes and in recreational and commercial fish production. Reduction of phosphorous discharge became a major concern in 1991, when seven States threatened or implemented action against fish hatcheries. The nutrient discharge problem was addressed through diet research and manipulation. Researchers at Tunison Laboratory of Fish Nutrition reduced one hatchery's phosphorous discharge by 50% without compromising nutrition or adding costs. Further reduction in available phosphorus in the diet could cause poor bone development without affecting growth. The addition of an enzyme to trout diets allowed digestion of normally indigestible phytin phosphorus, increased diet efficiency, and decreased phosphorous in discharged wastes.

Tunison researchers developed a starter diet for Atlantic salmon, using new, high-quality fish meals plus two compounds to enhance feed intake and osmoregulation. Fish fed the six-ingredient diet showed superior growth and survival. The high quality of ingredients and inclusion of lecithin and betaine enhanced growth and survival of fry. These results supported earlier Tunison research that found salmon do not require or benefit from a moist or semi-moist ration (expensive alternatives or supplements used in many production hatcheries) when nutritional quality of the ration is otherwise adequate.

Hatchery managers have used trout and salmon feeds for fingerling and adult striped bass, but the fish show excess body fat, poor food conversion, and tissue pathologies. Researchers at Tunison's Philadelphia Field Station and at the Fish Culture Laboratory in Leetown, West Virginia found that juvenile striped bass grew best when fed diets with amino acid patterns that simulated those of trout eggs or brine shrimp. Fish fed two such diets grew as well as, and had carcass compositions and protein efficiency ratios similar to, control fish fed the salmon diet of choice. No histological abnormalities were noted on fish fed the experimental diets. The two diets, having lower costs and slightly less protein than the salmon diet, can be used with minor refinements as prototypes of striped bass production diets.

Like many fish, fry of the striped bass and striped bass hybrids require live zooplankton as food. Fish farmers desire to manage their ponds so that zooplankton size is optimal as food for stiped bass when the fry are placed in the ponds. Ponds fertilized early in spring promote development of large zooplankters, some of which may be too large for smaller striped bass hybrids. Researchers at Stuttgart Fish Farming Experiment Station compared production of hybrid fry among ponds that received a variety of treatments. The highest survival of stocked 5-day-old fry at harvest 35 days later was from ponds that were filled with water at the time of spawning. The 59% fry survival rate exceeded the 10% to 20% usually obtained. Filling the empty pond basins on the day of spawning has been adopted by major hybrid striped bass producers.

Biologists conducting intensive tank culture of striped bass utilize brine shrimp as the primary food for first-feeding larvae. Nutrition research conducted at the National Fisheries Research Center–Leetown has shown that brine shrimp enriched with highly unstaturated fatty acids has greater nutritional value than unenriched brine shrimp and that fish fed enriched brine shrimp showed improved growth and survival over fish fed unenriched bring shrimp. A cold-storage culture system allows maintenance of newly hatched and enriched brine shrimp nauplii for extended periods.

Nutritionists at the Hagerman (Idaho) Field Station of the Tunison Laboratory of Fish Nutrition developed, from scientific literature, strategies that enabled catfish farmers and others to minimize feeding costs and to maintain fish health and body composition when catfish are held pending harvest. Cessation of feeding for a minimum of several days after fish have achieved the desired market size allows the fish to maintain equal body composition, provides growers with a savings in feed costs, and prevents unequal growth and other problems that would occur if food amounts were reduced.

Commercial Aquaculture Support

The Stuttgart, Arkansas, Fish Farming Experimental Laboratory staff respond to more than 15,000 requests each year about water quality, management, disease control, feeding practices, marketing, and more. Important aspects of the outreach program include disease inspections and water quality analyses. Additional support is provided by the Tunison Laboratory of Fish Nutrition and the Southeastern Fish Cultural Laboratory.

Channel Catfish Males Yield Better

Channel catfish males have a better meat yield and may be as much as 37% heavier than females raised in the same pond. Specialists at the Southeastern Fish Cultural Laboratory in Marion, Alabama, in cooperation with Memphis State University and the U.S. Department of Agriculture Catfish Genetics Research Laboratory, developed technology to produce all-male catfish. Several generations of hormone treatment and selective breeding produced super males, possessing YY sex genes rather than the normal XY genes. Hormones were used only on the grandparents, and never on fish grown for human consumption. Mating of the YY males with normal females produced only male offspring. Rearing confirmed that males grew faster and that production of all-male catfish could increase profits up to 20%.

At times, fish must be crowded for distribution or harvest. Their ability to tolerate handling varies by size, water temperature, water quality, and genetics. Researchers compared the stress response of four pure strains and nine strain crosses of channel catfish. Differences were detected that could be used in future breeding programs.

Although industry production is currently based on channel catfish, raising blue catfish may have advantages. Scientists compared catfish raised separately or communally in 0.04- and 0.2-ha ponds. Blue catfish grew less than channel catfish in the smaller ponds, but had equal growth and food conversion efficiency in larger ponds. Blue catfish were easier to capture (97.7% were captured in the first seine haul vs. 62.6% of the channel catfish), and dress-out weight (without head, skin and viscera) was 2.6% higher for blue catfish.

Culture Technology

Scientists at the National Fishery Research and Development Laboratory–Wellsboro exposed lake trout to fluctuating temperatures and gas supersaturation pressures to evaluate relations with clinical blood values. Temperature change for 16 h per day had more effect than saturation changes. Presence of warmer water increased white blood cell counts and decreased hematocrit and plasma protein. Fish subjected to 90 days of fluctuating water quality did not die or show long-term health effects, but all fish showed physiological stress response that was impaired at higher temperatures or pressures.

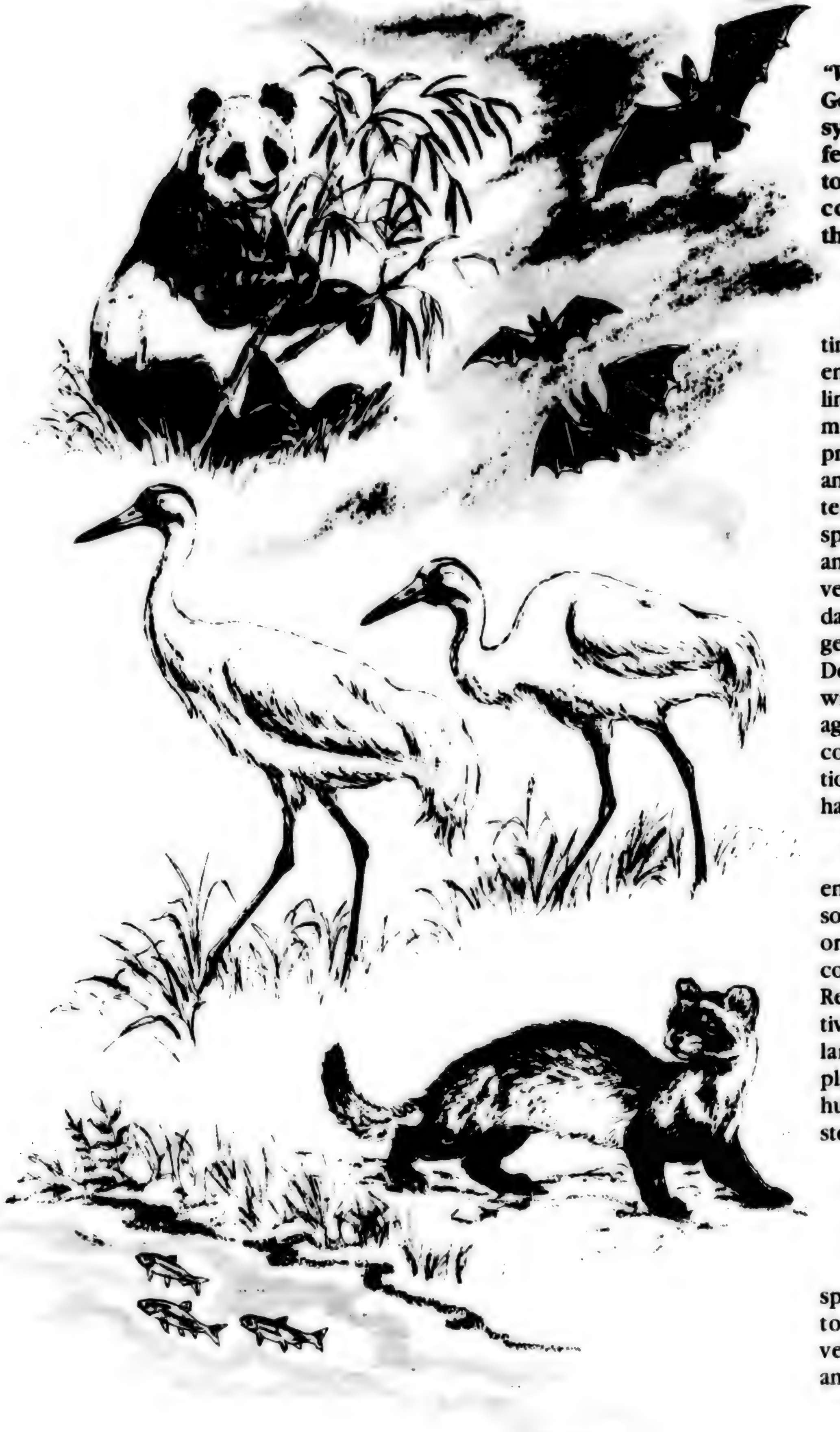
Use of pure oxygen absorption equipment provided substantial improvements in fish production and health. Researchers developed a portable packed column system that provided manual and automatic control of effluent dissolved oxygen and nitrogen. Dissolved gas pressures were regulated automatically with a unique control system. The system reduced highly supersaturated incoming water to below saturation (9–39%). High efficiency of the system permitted hatcheries to reduce supersaturation in their water supply by treating and blending back only a portion of the incoming water flow.

Verification of a gas transfer model at subatmospheric pressure led to the development of a new design procedure for packed column systems based on gas pressure limits as well as required oxygen supplementation and other standard performance indicators. A dissolved gas monitoring system was developed to eliminate submerged analytical components, reduce fouling, and improve reliability of continuous measurements. The system reduced cleaning and recalibration by 67%.

Currently, only one drug (MS-222) is registered as a fish anesthetic, and it has disadvantages for American shad. Researchers at the National Fisheries Research Center–La Crosse evaluated the drug metomidate to determine whether or not it reduced stress during handling and transport. Results showed no differences between treated groups and controls in post-recovery or mortality. If approved for use, the drug could be helpful in handling shad.

The National Fisheries Research Center–La Crosse, in cooperation with the University of Zululand, South Africa, studied fish anesthetization. Lake trout, channel catfish, and northern pike were anesthetized using electric current without inducing physical damage. Any electronarcosis of Atlantic salmon routinely caused injury. Species sensitivity and succeptability to injury depended upon the alternating current wave form. Although lake trout were sensitive to alternating current, use of pulsed direct current was more successful in anesthetizing individuals and was less physically damaging. Northern pike (60–80 cm), collected from the Mississippi River for spawning, were anesthetized using pulsed direct current. The fish recovered within 2–5 min and were released the same day, showing electronarcosis can be a viable alternative to chemical anesthetics for some fish.

Endangered Species



"VISION for the future"
Goal: To manage species, ecosystems, and human-induced effects to prevent species decline; to accelerate the listing and recovery of endangered and threatened species.

Research and Development centers and their scientists are intimately involved with the specific endangered species strategies outlined in *VISION for the future* document. Research and Development provides major attention to monitor and assess populations and ecosystem trends, identify species, subspecies, and populations in decline, and initiate balanced actions to prevent species from becoming candidates for listing under the Endangered Species Act. Research and Development scientists cooperate with Fish and Wildlife Service management to provide leadership in cooperative national and international efforts to restore ecosystems, habitats, and species that are declining world-wide. Research planning and strategies help promote environmentally and economically sound design and planning to avoid or minimize endangered species conflicts with human development. Research and Development's objectives are to discover and identify land management practices and plasticities of animals that balance human needs and uses with wise stewardship of fish and wildlife.

Research has developed partnerships with other Federal, State, Native American, local governmental, and private groups to identify candidate species or species in decline and to provide information to develop Recovery Plans. Research and Development has accepted the opportunity to emphasize research on threshold species on the verge of recovery and on critically endangered species to help develop innovative recovery actions. Research and Development continues to work with other regional personnel, Fish and Wildlife Service Public Information Offices, and professional and lay groups to help involved citizens understand the need for conservation of the world's biological diversity.

Threatened and Endangered Birds and Mammals

Birds

Hawaiian Forest Birds

Continuing research by the Patuxent Wildlife Research Center, Laurel, Maryland, in Hawaii during 1991–92 concentrated on determining factors that limit the current distribution and abundance of endangered forest birds. Surveys by Research and Development biologists indicated continued decline of many species of endangered and non-endangered birds. Research by scientists at Patuxent has focused on the population dynamics and limiting factors of the palila and its dry forest habitat. Since 1980, the palila population has ranged between 1,300 and 6,000 birds and currently is less than 1,500 birds. The palila research will serve as a model for studies to evaluate limiting factors of endangered Hawaiian forest birds within the wet forest habitat. Researchers at Patuxent were joined by scientists of the National Wildlife Health Research Center, Madison, Wisconsin, who are studying avian diseases and their effect on the Hawaiian birds.

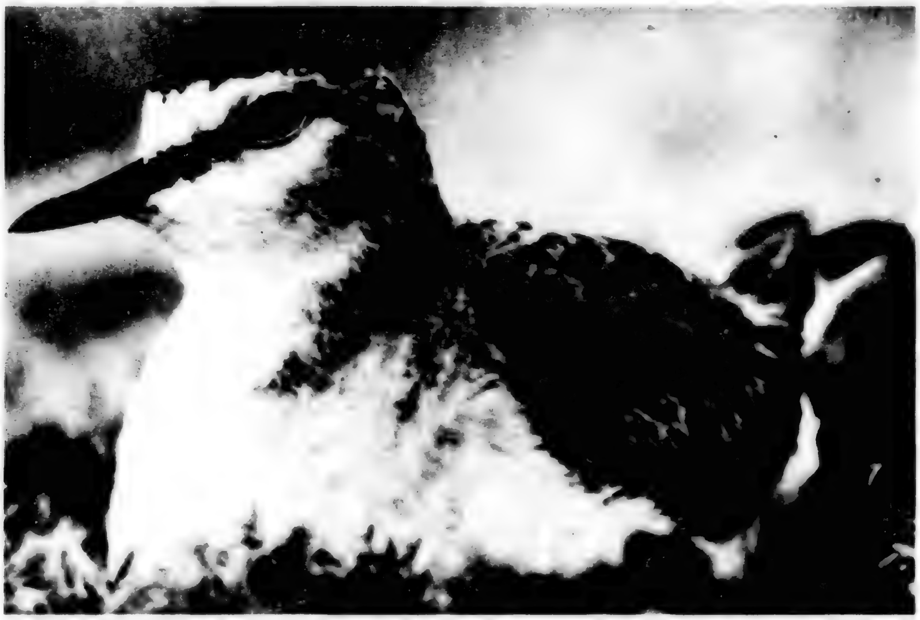
Kirtland's Warbler

During 1990 and 1991, 312 Kirtland's warblers were captured and color-banded during 19,600 h of operating nets at four study sites in northern lower Michigan. The team was lead by biologists from the Patuxent Wildlife Research Center. During the same period, 204 adults and 212 first-year birds banded in previous years were sighted by observers or captured in nets. The return rate was 58% for adults and 30% for first-year birds returning to Michigan after wintering in the Bahamas. Because all known nesting colonies were surveyed for color-banded birds, rates were probably close to the true overwinter survival for the species.

Between 1971 and 1989, the estimated number of singing male Kirtland's warblers averaged about 200, in spite of intensive management in Michigan. The Kirtland's warbler study was initiated to determine if mortality during migration or wintering was sufficient to account for the lack of population growth. Over the last 4 years (1987–91) the number of singing males in Michigan increased from 207 to 212, 265, and 347, respectively, mainly because a large block of habitat resulting from a wildfire in 1980 became available. The population grew about 25% per year in 3 of the 4 years. Fish and Wildlife Service biologists conclude that overwinter mortality is not a factor limiting Kirtland's warblers, and that lack of adequate breeding habitat in Michigan has been the most severe stress to this endangered neotropical migrant.

Mountain Plover

The 1988 Amendments to the Endangered Species Act directed



The mountain plover is the subject of extensive surveys throughout the western states. The mountain plover makes use of prairie dog ecosystems for breeding habitat. Habitat managed by prairie dogs seems to be important for several western species.

the Fish and Wildlife Service to monitor population trends of species that are candidates for listing. Breeding Bird Survey data indicate that the continental population of the Mountain Plover has declined more than 50% in the last 2 decades. Biologists at the National Ecology Research Center, in cooperation with the Northwest and Mountain–Prairie regions, the Bureau of Land Management, and the Forest Service, have initiated extensive surveys of plover populations throughout the western States. Intensive monitoring took place in Weld County, Colorado, and Phillips County, Montana, where more than half of the continental population of plovers breed. The mountain plover inhabits prairie dog ecosystems at many breeding locations. The earlier extirpation of black-footed ferrets from the wild, the dependence of two other candidate species (ferruginous hawk and swift fox) on prairie dog colonies, and the association between prairie dogs and mountain plovers have drawn attention to the significance of prairie dogs and their managed environment to many endemic species of the western Great Plains.

1991 International Piping Plover Census

In 1991, a comprehensive assessment of piping plover numbers was undertaken by the four piping plover recovery teams in the United States and Canada. More than 800 people from seven nations participated in the winter and summer censuses to make this the most extensive, single-species, non-game or endangered species census ever conducted in North America.

More than 5,000 adult piping plover were counted during the breeding season. This represented more piping plover than had ever been reported in the past, but the number of breeders remained low. The winter census located about 60% of the breeding birds. Because of the low number of breeders, a recommendation was made to change the status of the species in the United States from threatened to endangered.

Northern Spotted Owl

Past data gathered from more than 2,000 marked female northern spotted owls were analyzed by using methods of model building, model selection, tests of model fit, parameter estimation, and inference procedures concerning the rate of population change. Led by scientists of the Colorado Cooperative Fish and Wildlife Research Unit and the Oregon Cooperative Wildlife Research Unit, six owl biologists and six capture–recapture analysts modeled the data obtained from resident territorial females from five large study areas in northern California, southern Oregon, central Oregon, and the Olympic Peninsula in northwestern Washington.

The model parameters of interest were the annual rate of change in size of the population of females and the annual probability of survival of the adult females. By using the model, researchers can determine if females are replacing themselves. If so, the population is either stable or increasing; if not, the population is declining. The results showed that all five populations were declining by about 7.5% per year during the 6 years of the study. Populations on the study areas were augmented by immigration of new individuals each year, but the additions were insufficient to slow the increasing rate of decline that was occurring from the early to later years of the study.

Mexican Spotted Owl

The Fish and Wildlife Service proposed the Mexican spotted owl for listing as threatened in 1991 because of small population size and reductions in available forested habitat. Based on a single study conducted in Arizona, the U.S. Forest Service developed interim management guidelines that provided for 182-ha core areas in New Mexico and Arizona. No habitat disturbance except roads was allowed in core areas. Fish and Wildlife Service biologists gathered additional data on range size and roosting and nesting site characteristics in New Mexico to augment the Arizona study.

Range size in New Mexico averaged 742 ha for individuals and 1,128 ha for mated pairs. The ranges were 14% and 39% larger, respectively, than in Arizona. Roost and nest site characteristics were similar to Arizona sites. In both States, Mexican spotted owls roosted and nested in dense, uneven-aged mixed conifer or ponderosa pine forests with 80% canopy closure. Douglas firs were used for nests more than any other tree species.

Maintaining Genetic Diversity of Translocated Red-cockaded Woodpecker Colonies

An extensive translocation program is under way across the southeastern United States in an attempt to replenish declining red-cockaded woodpecker populations. Only arbitrary guidelines for choosing donors or recipients of birds were available when the project was initiated. Coordinated by the South Carolina Cooperative Fish and Wildlife Research Unit, the project uses state-of-the-art genetic techniques (i.e., Random Amplified Polymorphic DNA (RPAD) analyses) to identify differences and similarities among populations to ensure that no population will suffer a loss of genetic diversity as a result of the translocation program.

Recovery objectives include an effective population size that must be met before down-listing the species. Unfortunately, the effective population size values were calculated without considering the cooperative breeding social system of the birds. In red-cockaded woodpeckers, several males may father chicks in a single brood, making the conventional estimation of effective population size inaccurate. To make a more accurate estimate of effective population size, DNA fingerprinting will be used to determine parentage among woodpecker families.

Red-cockaded Woodpecker in Oklahoma

Biologists at the Oklahoma Cooperative Fish and Wildlife Research Unit studied habitat selection of a remnant population of red-cockaded woodpeckers in southeastern Oklahoma on the edge of the species' range. The number of clans declined 62% (from 29 to 11) and individuals declined 74% to 76% (from 86–92 to 22) since 1977. Productivity was low; only 0.69 young per nesting attempt were fledged.

Red-cockaded woodpeckers selected forest habitats having low hardwood densities for cavity sites and high pine densities for foraging habitat. Eighteen active cavity trees were compared to 18 paired non-use sites. The area surrounding the cavity trees had significantly shorter hardwoods and less hardwood basal area than non-use sites. The 0.01-ha quarter directly in front of active cavities had significantly shorter hardwoods, hardwoods with smaller diameters breast-height, and less hardwood basal area than the remainder of the area surrounding cavity trees. Hardwood densities at cavity trees were greater than recommended by the recovery plan, indicating the necessity to reduce hardwoods in the area. Overall, foraging habitat met minimal requirements established in the Red-cockaded Woodpecker Recovery Plan.

Masked Bobwhite

Captive masked bobwhites (about 110 pairs) maintained by the Patuxent Wildlife Research Center produced more than 20,000 eggs in the last 2 years. Fertility of eggs exceeded 60%, and 80% of the incubated fertile eggs hatched. Although many eggs were not incubated, more than 1,000 new individuals were added to the pedigree captive flock; and about 5,000, 2-week-old chicks were shipped to the Buenos Aires National Wildlife Refuge for release. While hundreds survive to breed on the refuge each year, it is not yet certain that a self-sustaining population has been established.

Puerto Rican Parrot

Productivity of the population of wild Puerto Rican parrots was

Reproduction in Puerto Rican parrots was reduced by Hurricane Hugo. The parrots reversed the trend the next year when a record six nesting pairs was discovered. *Photo by J. Colon.*

Brown tree snakes climb trees and consume endangered birds on Guam and nearby islands. An inexpensive trap has been found useful in some local situations.

reduced the year after Hurricane Hugo. That changed drastically in 1991 when a record six nesting pairs was discovered, and eight parrots were successfully fledged in the wild. Cooperative efforts of the U.S. Forest Service, Puerto Rico Department of Natural Resources, and U.S. Fish and Wildlife Service (Southeast and Research and Development regions) resulted in a population increase to 30 wild parrots from 23 following the hurricane. Using exotic parrots, biologists at Patuxent Wildlife Research Center are currently experimenting with marking and capturing techniques in Puerto Rico and are analyzing information collected on habitat and activity of breeding and nonbreeding Puerto Rican parrots. The data will help in the release of captive-reared parrots and to restore the population.

Protecting Birds by Trapping the Introduced Brown Tree Snake in Guam

The search for an effective, commercially available trap to capture tree snakes that eat nesting endangered birds on Guam was successful. In a comparison recently completed by researchers from the National Ecology Research Center, commercial minnow traps have proven useful. Off-the-shelf minnow traps with 1-inch funnel openings can be used as snake traps. The minnow traps are durable, affordable, easy to use, and can be disassembled and nested for storage. The addition of flaps and glueboards to prevent snakes from leaving traps makes them more effective. The availability of large numbers of traps of durable material and uniform quality is important for control of snakes in selected sites on Guam and capture of new snakes introduced on other islands by ships and airplanes.

During a recent experimental snake control project on the Guam Naval Station in central Guam, 121 snakes were removed by trapping from a 1.4-ha plot (86 snakes per ha) in a 15-day period. The rate of removal did not seem to reduce the number of snakes present. Lack of population reduction suggested that the number actually present was substantially higher or that snakes were moving into the area from adjacent habitats at about the same rate of the removal. The density of snakes is high in selected areas and attempting to eliminate them using existing techniques is a formidable task. Traps and hand capture are effective for small areas where control of the snake population is critical, but may be impractical for larger areas. New techniques are needed that have a significant effect on the island-wide snake population on Guam and other large areas.

Genetic Evaluation and Population Management of the Guam Rail and Micronesian Kingfisher

Most native bird species on Guam are extinct as a result of introduction of the brown tree snake during World War II. The last Guam rails and Micronesian kingfishers were placed in captivity in 1985. The current project seeks to develop a successful captive breeding strategy and design a reintroduction strategy to ensure future viability of the new wild populations of both bird species.

Demographic analyses, electrophoresis, DNA fingerprinting, and pedigree management analyses were completed for both species. Recommendations for captive management emphasize maintenance of genetic diversity of the founders, or original birds brought into captivity. The strategy provides for management of allele representation and heterozygosity. A reintroduction strategy has been designed and implemented for the rails and one is being developed for kingfishers.

Mississippi Sandhill Crane

The Mississippi sandhill crane, an endangered subspecies of the sandhill crane, has a small population (six nesting pairs in 1991) occupying a remnant (part of one county centered on the Mississippi Sandhill Crane National Wildlife Refuge) of its former range along the Gulf Coast from Louisiana to Florida. Pairs in the wild have not produced enough young to maintain or increase the population. Only the release of captive-reared birds from the Patuxent Wildlife Research Center has maintained the population.

In 1986, biologists modified the crane hand-rearing program to promote imprinting of chicks on adult cranes, not on human caretakers. By 1989, rearing techniques included use of stuffed crane brooder models, stuffed crane head feeding models, a live crane (imprinting model) penned next to neonatal chicks, adult cranes to serve as socialization models for developing chicks, and crane costumes for all caretakers. Since 1989, the Fish and Wildlife Service has released more than 100 parent-reared and costume-reared Mississippi sandhill cranes. With these releases, the wild population has increased from about 55 to more than 120 birds. More of the parent-reared and costume-reared cranes survive than do wild birds of a like age.

For the past 2 years, the behavior of nesting pairs during incubation, hatching, and early chick life has been examined by using a remote sensing closed-circuit television camera system. Activity at nests under surveillance was recorded 24 h per day on color video cassettes in conjunction with a date-time generator. To date, problems identified include flooding of nests, predation, inexperience of pairs, insufficient number of pairs attempting to breed, and poor quality of habitat because of previous land-use practices (drainage and planting of pine trees in wet savannas and fragmenting of habitat by highway corridors and development).

Satellite Telemetry

The Patuxent Wildlife Research Center's 3-year satellite telemetry study with cranes will end in fall, 1992. Using captive sandhill cranes, scientists at the Center developed new harnessing methods and devices that were tested on wild cranes in Siberia. A cooperative Canadian–United States study of North American cranes that will use information from the telemetry study will begin in 1993. If successful, the methods may be used with whooping cranes.

Avian Tuberculosis in Whooping Cranes

Avian tuberculosis (TB) was found at an alarmingly high rate in whooping cranes. The disease was diagnosed in 7 (28%) of 25 whooping cranes examined by scientists at the National Wildlife Health Research Center since 1975. Five of seven cranes were from the Rocky Mountain flock. Infected birds from this flock were from Wyoming, Colorado, and Idaho. Two cases of TB were found among eight cranes from the Wood Buffalo flock; both were from wintering grounds in Texas. Researchers investigated the prevalence of TB in sandhill cranes and snow geese that associate with the Rocky Mountain whooping cranes. Samples from more than 400 hunter-killed sandhill cranes and snow geese from Wyoming and New Mexico were cultured. The bacterium that causes TB was cultured in only one sandhill crane. This low frequency (<1%) is similar to the low prevalence usually found in other wild birds. The high prevalence in examined whooping cranes suggests that this species is highly susceptible to TB or is exposed to the bacteria more frequently or at higher levels than other birds.

U.S. Fish and Wildlife Service health specialists have isolated avian tuberculosis in sandhill cranes. Five of seven infected birds were from the Rocky Mountain flock. The other two diagnosed were from the Wood Buffalo flock that were wintering in Texas.

Mechanical Egg Incubation

Hatchability of crane and other non-domestic bird eggs incubated in mechanical incubators is usually less than eggs incubated by parents. Eggs incubated by parents or surrogate parents are susceptible to many risks: predators, adverse weather, bacterial contamination, and accidental or deliberate breakage by foster parents. Scientists at Patuxent Wildlife Research Center have developed a new incubator that simulates the conditions found in the nest of incubating sandhill cranes. The new system includes an artificial egg containing sensors that monitor incubation conditions, an automated system to receive data from the egg, and a computer-operated receiving and recording system. The computer controls incubation temperatures, simulating the conditions found in the nest. The incubator is being tested by using a small number of crane eggs. The goal is to increase hatchability of eggs from 65% (common in incubators) to 85%, the expected hatch rate from proper parental incubation.

Mammals

Minnesota Gray Wolf

Wolves are classified as threatened in Minnesota and as endangered in neighboring Wisconsin and Michigan. Wolf recovery in the region depends on dispersal of wolves from Minnesota. Canine parvovirus (CPV), a new disease of domestic dogs, was discovered in Minnesota wolves several years ago. Recent research in Minnesota indicates that CPV may be affecting the wolf population. Based on 12 years of population and serological research, evidence indicates that wolf pup survival each summer and percent annual change in wolf numbers each winter are related to annual incidence of CPV. This finding may explain why wolf recovery in Wisconsin and Michigan has been slow.

Sonoran Pronghorn

From April to August 1988, and from March to August 1989, Fish and Wildlife Service biologists studied vegetation in habitats used by Sonoran pronghorn on the Cabeza Prieta National Wildlife Refuge and the Organ Pipe Cactus National Monument in southwestern Arizona. They sampled known forage plants monthly throughout the summer at sites used by pronghorns. Scientists analyzed fecal pellets to estimate dietary preferences and analyzed forage samples for various nutritional components. Sonoran pronghorns fed on succulent cacti during the dry season (December–July), even though the protein content was low. The pronghorns selected more forbs during the wet season (August–November) than other types of forage. Protein in plants from occupied areas was higher than in plants from unoccupied areas. The proportion of indigestible material (e.g., cellulose) in plants from occupied areas was generally less than that in unoccupied areas. Cover, number of plants, and vertical structure were generally greater in occupied areas than in unoccupied areas.

Recovery of Ozark Big-eared Bat

Historically, the endangered Ozark big-eared bat was found in eastern Oklahoma, western Arkansas, and southwestern Missouri. Current range has decreased significantly, and the bat is believed to be extirpated from Missouri. Only 200–250 Ozark big-eared bats were known to exist before the completion of the first phase of on-going research by scientists at the Oklahoma Cooperative Fish and Wildlife Research Unit. Adult females in maternity caves and both sexes in hibernacula have been counted annually since 1984; researchers have now located 700–800 individuals of this non-migratory species that use only five caves throughout the year. Eighteen females were tagged with 0.8-g transmitters. Mean distances traveled from the maternity cave to geometric centers of foraging areas increased from 1.0 km during early lactation to 2.2 km during mid-lactation to 3.7 km during late lactation. Maximum distance traveled to a foraging area was 7.3 km. The Ozark big-eared bat eats moths (91.4% of diet) and uses wooded and edge habitats associated with intermittent streams and mountain slopes. Personnel at the new Oklahoma Bat Caves National Wildlife Refuge used these data to identify and protect critical habitats and enhance recovery of this endangered species.

Black-footed Ferret

Introductions of captive-raised black-footed ferrets seem the only hope for ferret re-establishment in the wild because no free-ranging ferrets have been located. In 1988, scientists from the National Ecology Research Center and the Conservation and Research Center of the National Zoo began research on the closely related Siberian ferret with the ultimate goal of re-establishing black-footed ferrets in the wild. Research methods paralleled the California condor program in its use of a surrogate species to test reintroduction techniques.

Captive environments can have profound effects on the natural behavior and physiology of an animal. Researchers investigated the ontogeny of behaviors critical for survival, compared those behaviors in different captive environments, tested several release techniques with neutered Siberian ferrets, and fine-tuned the telemetry system to be used on reintroduced black-footed ferrets. Pre-release conditioning of animals in large, indoor prairie dog colonies was encouraging.

Scientists at the National Ecology Research Center evaluate the Meeteetse, Wyoming, prairie dog complex each year for its ability to support black-footed ferrets. Data from the past 5 years indicate the persistence of sylvatic plague. Because the Meeteetse complex was unsuitable, black-footed ferrets were released at the Shirley Basin prairie dog complex in Wyoming. During September and October 1991, 49 black-footed ferrets were released from elevated holding cages; 37 were equipped with radio-collars. Cages were to provide a post-release source of food, water, and refuge from predators. Most instrumented ferrets left the cages within 24 h. Seventeen ferrets dispersed up to 17 km from the release area; predators killed six (five by coyotes and one by a badger). Three ferrets suffering from malnutrition or injury were recaptured and rehabilitated. Fish and Wildlife Service researchers and Wyoming Game and Fish biologists confirmed that at least nine ferrets remained in the core release area on 14 November 1991; on 10–11 March 1992, at least three ferrets remained.

A second release of captive-raised black-footed ferrets is planned for fall 1992 at Shirley Basin, Wyoming. Only one release technique was used in Wyoming, but at least two techniques will be used in future experimental reintroductions. This comparative approach should lead to the optimal operational release technique.

Threatened and Endangered Fishes and Other Aquatic Organisms

The Fish and Wildlife Service and State agencies have an avid interest in determining the ecology, behavior, life history, and other aspects influencing populations of threatened or endangered fishes. Fish pres-

Wild black-footed ferret from 1984, Meeteetse, Wyoming. *Photo by D. Biggins.*

Releasing radio-telemetered captive-raised Siberian polecats in a Wyoming prairie dog town. *Photo by D. Biggins.*

ence under water is often difficult to detect and sample, and the environmental factors of their medium can be exceedingly complex. Rigorous scientific procedures must be developed to protect these populations of rare aquatic organisms and their associated habitats. Presented below are several brief examples of research the Fish and Wildlife Service is conducting on threatened or endangered fish and aquatic invertebrates.

Shortnose Sturgeon

Scientists and students at the Conte Anadromous Fish Research Center–Turners Falls and the Massachusetts Cooperative Fish and Wildlife Research Unit recently completed several studies on the movements and ecology of shortnose sturgeon. A small, undiscovered population was found in the Merrimack River, where adults use two river reaches during the year. Inadequate substrate conditions for egg and embryo survival may be limiting population abundance. Laboratory studies showed that protection of a spawning site containing eggs and hatchling embryos for 30 days facilitated survival. Additional study of the Connecticut River population revealed the location of a second spawning site and that the landlocked population upstream of Holyoke Dam was not naturally landlocked, only damlocked. Voluntary downstream movement past the dam was found annually, but upstream movement was prevented by the dam and inefficient fishways.

Habitat Needs of Pallid Sturgeon

Scientists at the South Dakota Cooperative Fish and Wildlife Research Unit followed seven endangered pallid sturgeons tagged with sonic transmitters in the upper end of Lake Sharpe, South Dakota, and obtained habitat data from more than 500 relocations. The sturgeon preferred the river area and transition zone between the river and the lake. Pallids were previously believed to prefer strong river currents, but the tagged fish used deep water with slow currents.

Cui-ui in Nevada

The cui-ui, a Federally listed endangered species native to Pyramid Lake, Nevada, has declined in population in this century as a result of the country's first Bureau of Reclamation project. The Newlands Project diverted water from the Truckee River, Pyramid Lake's primary source, to irrigate lands in the Carson River Basin. Subsequently, Pyramid Lake subsided and a delta formed at the Truckee River mouth, and cui-ui, which are lake dwellers but stream spawners, were unable, in most years, to physically enter the Truckee River for spawning. Research conducted by scientists at National Fisheries Research Center–Seattle has led to development of a water management model that establishes the timing and volume of flows sufficient to allow river entry and spawning, a major step toward recovery of this species.

Suckers in Oregon

The shortnose and Lost River suckers were Federally listed as endangered in 1988. Native to the Klamath River Basin of Oregon and California, their populations have steadily declined for the past 30 years. Ecological studies conducted by the National Fisheries Research Center–Seattle found that lethal conditions of low dissolved oxygen and excessive alkalinity occur in Upper Klamath Lake. During summer months, up to 90% of the lake is rendered uninhabitable for all life stages of suckers of both species. Management agencies have focused on measures to improve the lake's water quality through marsh restoration and stabilization of lake levels.

June Sucker in Utah Lake

The June sucker, an endangered fish, is a long-lived native of Utah Lake whose numbers have drastically declined. A recent cooperative study by the Utah Division of Wildlife Resources, the Fish and Wildlife Service, and Utah State University showed that June sucker spawning did occur and that the young migrated into Utah Lake. Thus, unsuccessful reproduction was eliminated as a cause of population decline. Researchers doing laboratory feeding studies during the same project found that June sucker larvae and juveniles feed on zooplankton. Zooplankton was also the diet of choice for gizzard shad in Utah Lake. Initial pen experiments showed that competition from differing densities of gizzard shad did not affect June sucker growth or mortality.

Predator Recognition in Suckers

Recent attempts to reintroduce razorback suckers into native habitats were unsuccessful. Razorback suckers are native to the mainstream Colorado River, which originally supported only one native fish predator–the Colorado squawfish. Conversely, northern hog suckers evolved in a predator-rich environment, indicating that this subspecies should be able to quickly recognize predators.

Scientists at the Arkansas Cooperative Fish and Wildlife Research Unit found that over a period of 2 months after hatching, untested single razorback sucker larvae improved their predator recognition and avoidance rate. Northern hog suckers recognized and avoided a predator earlier than razorback suckers and completely avoided the predator 30 days after hatching.

Five untested larval razorback suckers placed in the test chamber initially showed predator recognition and avoidance similar to single larvae. They did not, however, improve as rapidly or as extensively as did single larvae. More surprising, groups of five northern hog sucker larvae had little better predator recognition than did razorback suckers. Stocking razorback suckers at least 60 days of age provides an improved opportunity to avoid predators. Removal of non-native predators also would aid recovery efforts.

Apache Trout in Arizona

In the Southwest, researchers with the Arizona Cooperative Fish and Wildlife Research Unit examined habitat requirements of Apache trout. The Apache trout found were in pools with the most instream cover and bankcuts. Areas occupied had significantly greater depths, larger volumes of water under instream cover, and larger areas under bankcuts than did unoccupied areas. Adequate nursery habitat and successful reproduction was found on some creeks. Nursery habitat (sand, gravel, and gravel substrate) was lacking on several Apache trout streams. No evidence was found of successful reproduction in streams with inadequate nursery habitat. Small Apache trout seldom inhabited areas where non-native trout were numerous. The trout were found, however, in areas having few non-native trout. Apache trout basked in pools during part of the day, but coexisting brown trout occupied cover during the entire day. When Apache trout returned from basking and sought cover, they were unable to displace the larger brown trout.

Stocking Colorado Squawfish

Researchers at the Colorado Cooperative Fish and Wildlife Research Unit studied Colorado squawfish stocking in Kenny Reservoir near Rangely, Colorado. They examined ecology and behavior to develop a possible squawfish sportfishery in Kenney Reservoir as part of a mitigation program for the construction of Taylor Draw Dam on the White River. A total of 96,597 fingerling squawfish was stocked into Kenney Reservoir from 1988 to 1990. These fish quickly dispersed throughout the reservoir and downstream into the White River. A small number moved upstream in 1990. A large proportion, associated with high discharge following stocking, exited over the spillway and moved downstream. Catch-per-unit-effort declined drastically in both the river and the reservoir in 1989 and 1990. The rapid disappearance of squawfish throughout the study area was attributed to flow regime, movement patterns, mortality, or sampling effectiveness, or a combination of these factors. In this situation, stocking squawfish in a reservoir was not an effective mitigation procedure for habitat loss.

Neosho Madtom

Fish biologists from the Oklahoma Cooperative Fish and Wildlife Research Unit and the Zoology Department at Oklahoma State University assessed the status of the threatened Neosho madtom, a small member of the catfish family. They examined 24 sites, including new locations never before sampled. The only madtoms (14) captured were in the Neosho River at six mainstem riffles with uncompacted gravel substrates. The present rarity of these sites has resulted largely from construction of reservoirs. Lack of suitable habitat seems to be the primary factor limiting the abundance of this rare species in Oklahoma.

Endangered and Threatened Fishes of the Southeastern United States

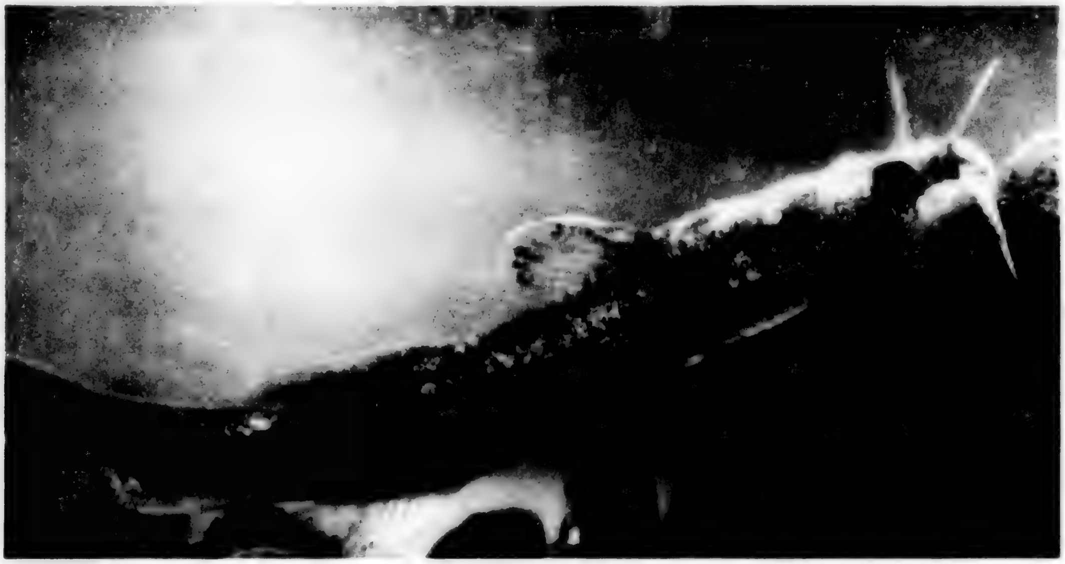
Threatened and endangered freshwater fishes in the southeastern United States are generally represented by two classes of imperilment. The first class consists of species with naturally restricted geographic distributions. The other class of imperilment reflects the pattern of jeopardy seen in the majority of declining, threatened, and endangered freshwater fishes found in the southeast.

The Okaloosa darter is an example of endangerment by restricted geographic distribution. This small member of the perch family is native to six small tributaries of the lower Choctawhatchee Bay drainage on the Florida panhandle and is naturally vulnerable because of its small total range. Natural vulnerability, however, has been exacerbated by the introduction of the non-native brown darter. The brown darter is ecologically similar to the Okaloosa darter and has replaced the Okaloosa darter in portions of its native streams. The Okaloosa darter also has been affected by land-use practices on Eglin Air Force Base, where most of the darters live. Ichthyologists from the National Fisheries Research Center–Gainesville have been conducting ecological studies to describe the nature of the ecological interactions between the Okaloosa and brown darters in hopes of devising management plans for the protection and recovery of the Okaloosa darter.

About 15% of the approximately 500 species found in the southeast are endangered because of a chronic loss of populations that persists throughout the range of each species. When the range of a species becomes small and fragmented, the individual populations and the total species becomes vulnerable to further population loss and catastrophic events, and to the natural processes of extinction. The primary causes of imperilment of southeastern freshwater fishes are massive habitat alteration, fragmentation, and loss by impoundment, pollution, and siltation. The endangered boulder darter, a fish native to the Elk River in Tennessee, is an example of a species that has precipitously declined to become one of the most imperiled fishes in the south. Biologists at the National Fisheries Research Center–Gainesville are studying the reproductive biology of the boulder darter to gain understanding of habitats critical to its spawning.

Arkansas River Shiner

The Arkansas River shiner is a 2-inch minnow once widespread and abundant in the Arkansas River and its major tributaries. In the last two decades, however, populations declined drastically in distribution and number. Endangered fish specialists from the Oklahoma Cooperative Fish and Wildlife Research Unit and the Zoology Department at Oklahoma State



The Neosho madtom is listed as threatened and needs riffles of uncompacted gravel as habitat. Lack of suitable habitat seems the primary limiting factor of this rare species in Oklahoma. *Photo by G. Luttrell.*

University made collections throughout the southern Great Plains to document the current distribution and status of this soon-to-be-listed species. Populations were restricted to the South Canadian River from below Ute Reservoir in eastern New Mexico to Lake Eufala in eastern Oklahoma. Researchers discovered that high flows during summer seemed essential for successful reproduction. The frequency and degree of peak flows have declined in upstream areas within the Arkansas River drainage, and many dams now obstruct the shiner's migratory patterns. Any new water resource development projects will require careful evaluation to prevent extinction of the Arkansas River shiner.

The Arkansas River shiner apparently needs high water flows during summer to successfully reproduce. Water flows have stabilized by upstream water management in Oklahoma and New Mexico. *Photo by R. Larson.*

Newts

Striped Newt

Biologists from the National Ecology Research Center–Gainesville field station completed data analysis from a 5-year study of the striped newt, a candidate for Federal protection. They conducted the study at a temporary pond in upland habitat of north-central Florida, where more than 2,500 newts were captured immigrating to and emigrating from the pond. Striped newts entered the pond any time from late fall through late spring, depending on when rainfall formed the pond. When the pond dried, the newts emigrated but returned if rains occurred later in the season. Reproduction successfully occurred only once in 5 years, and even during that year, only a few metamorphosed juveniles were captured. The breeding population declined significantly as drought severity increased. The lack of a clearly defined sex differential on arrival at the pond and the extended annual activity period for reproduction may be adaptations that allow striped newts to exploit randomly available temporary breeding habitats.

Threatened or Endangered Aquatic Invertebrates

The southeastern United States has more freshwater mussel species than any other region of the world. In the last 40 years, however, a precipitous decline in mussel populations was found throughout the southeast. Habitat degradation, the introduction of exotic bivalves (including the Asian clam and the zebra mussel), pollution, impoundments, and other factors have led to an alarming decline in unionid populations. Presently, 41 mussel species are listed Federally as endangered.

Rough Pigtoe Pearly Mussel

Scientists at the National Fisheries Research Center–La Crosse and the Tennessee Cooperative Fisheries Research Unit are determining the life history requirements of the endangered rough pigtoe pearly mussel. One cause of declining mussel densities may be a lack of suitable host fish needed to metamorphose the parasitic mussel larvae (termed glochidia) into juveniles. Surveys of populations in the Green and Barren rivers in Kentucky show that these mussels are most common in shoal and riffle habitats.

Examination of 1,638 fish representing 42 species from the Barren River showed that 7% had glochidia attached to their gills or fins. The frequency of infection of fish with glochidia ranged from none in February to 41% in March. Densities of the rough pigtoe pearly mussel were similar in the Green and Barren rivers (3.6 and 5.7 mussels/m^2), but density declined in both rivers between 1990 and 1991—possibly because of commercial harvest. Glochidia from a related species of mussel changed into juveniles on fathead minnows and river shiners in laboratory studies.

Freshwater Mussels

Scientists at the Virginia Cooperative Fish and Wildlife Research Unit, in cooperation with researchers at the College of Veterinary Medicine at Virginia Polytechnic and State University, have begun a long-term project to develop techniques for the laboratory culture of juvenile freshwater mussels. An artificial medium, modified from one developed by the Tennessee Valley Authority, in a CO_2-filled incubator was developed to transform glochidia to the juvenile stage without an intermediate fish host. Success of the medium with various additives was tested with various mussel species. The use of dialyzed fish serum, horse serum, rabbit serum, endothelial growth factor, or other media additives did not improve production of juvenile mussels. The health of the juveniles produced on artificial medium is being compared to the health of juveniles produced naturally.

International Endangered Species

Conservation of Reptiles in Paraguay

Paraguay has been one of the largest centers of illegal harvest and international trade in wildlife products in South America. Aided by international conservation organizations and biologists from the National Ecology Research Center, the country is developing the political and scientific infrastructure and enabling legislation necessary to implement a legal, sustained-yield harvest of wildlife. Current efforts are directed toward the management of two lizards–the red tegu and the black tegu–and two caiman–the Paraguayan caiman and the broad-snouted caiman. Their skins, worth millions of dollars annually, are the most valuable Paraguayan wildlife products in the international market. Tegu lizards are the most important species in the manufacture of western-style boots made of reptile skin. Caiman are already on the United States List of Endangered and Threatened Species.

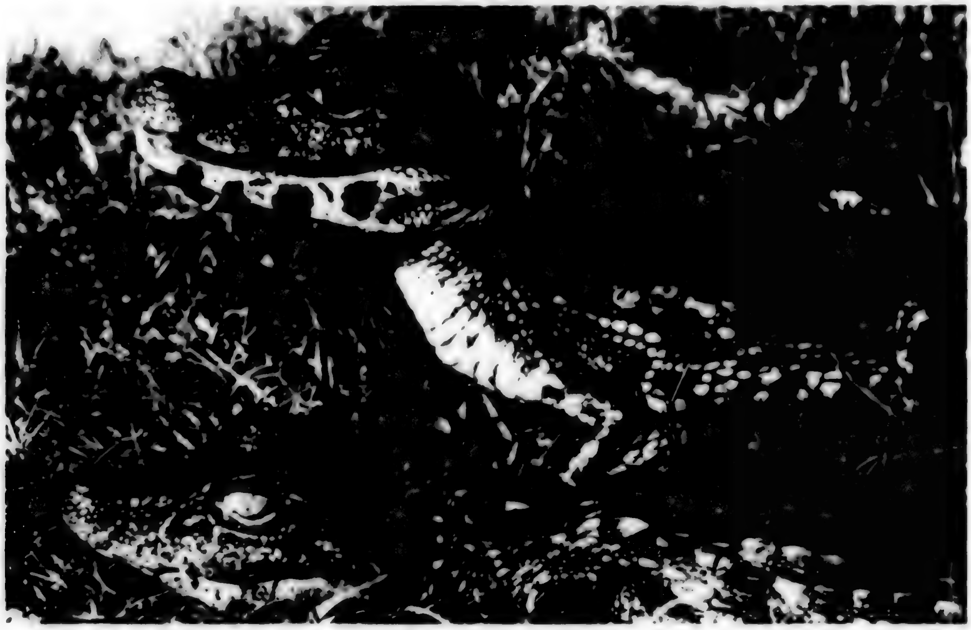
Biologists are studying the distribution, population biology, and status of lizards and crocodilians. Based on these studies, the Paraguayan government sets annual quotas for the legal exploitation of wild populations. The quotas will be of sufficient magnitude to assure a continuous supply of reptilian skins, and should provide an economic incentive for landowners to protect wildlife habitat from conversion to agriculture.

During field studies of the distribution and population status of the caimans, investigators from the Museo Nacional de Historia Natural del Paraguay and the National Ecology Research Center recorded for the first time the presence of a third crocodilian, Cuvier's dwarf caiman. They also found that caiman still occupy most of their historic habitats but that many populations are greatly reduced by illegal hunting, especially those of the broad-snouted caiman.

Foreign Species Listing Under the Endangered Species Act

The Office of Scientific Authority is responsible for conducting status reviews and initiating listing actions for foreign species qualifying for protection under the Endangered Species Act. From October 1990 to July 1992, the Office of Scientific Authority conducted status reviews of 2 crocodilians, 3 kangaroo species, and 53 bird species. As a result of these or pre-

The black tegu lizard is the reptilian species most widely used in the United States in the manufacture of western-style boots. Although hundreds of thousands have been taken annually for many years, they seem to persist, even in heavily populated suburbs of big cities. *Photo by N. J. Scott, Jr.*



Two species of caiman, the Paraguayan caiman and the broad snouted caiman, are exploited for their skins in Paraguay. These juveniles were taken from the same marshland, but adults seem to prefer different microhabitats. *Photo by N. J. Scott, Jr.*

vious status reviews, listing actions or changes in listing status were proposed for: argali (list entire species as threatened or endangered); African elephant (revise the special rule and uplist some populations to endangered); three butterflies (list as endangered); and three African antelope, the scimitar-horned oryx, addax, and dama gazelle (list as endangered). The white-necked crow and six reptiles were listed as endangered in 1991, and actions on argali sheep, the African elephant, and three butterflies will be completed in 1992 as a result of earlier status reviews and proposals prepared by OSA.

CITES Conference

During 2–13 March 1992, the Eighth Meeting of the Conference of the Parties to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) was held in Kyoto, Japan. The about 1,500 attendees included delegates from 103 of the 113 countries that were then Parties to CITES (there are now 117), observers from conservation and trade organizations, and journalists. To prepare for the meeting, the Office of Scientific Authority drafted United States positions on 14 CITES implementation proposals considered at the meeting. Among these proposals were a background document and a resolution on the responsibilities of the Office of Scientific Authority and counterparts in all Party countries. This resolution was adopted by the Parties and should further clarify and strengthen the scientific input to the implementation of CITES.

The Office of Scientific Authority also developed United States proposals and evaluated those of other Parties to amend the CITES Appendices (lists of protected species). A total of 123 listing changes was proposed for animals (18 prepared by the Office of Scientific Authority) and considered at the meeting; 59 were approved. Thirty listing changes were proposed for plants (4 from the Office of Scientific Authority), and 23 were approved. Many proposals were withdrawn because biological or trade information did not substantiate a listing or a change in listing status at the time, or because they duplicated other approved proposals. Proposals affecting animal species native to the United States and its territories consisted of: delisting the United States populations of Mexican and Sonoran pronghorn, the northern elephant seal, and the harlequin quail (all approved); captive breeding registration of Nicobar pigeons to treat them as Appendix II specimens for commercial purposes (withdrawn); transfer of the bog turtle from Appendix II to Appendix I (approved); addition of the wood turtle, coastal horned lizard, paddlefish, and queen conch to Appendix II (all approved); and addition of herring and bluefin tuna to Appendix I (both withdrawn). Proposals involving United States plants included transfer of a group of living-rock cacti from Appendix II to Appendix I and addition of Venus flytrap, Caribbean mahogany, and common lignum vitae to Appendix II (all approved).

At the meeting in Japan, Office of Scientific Authority biologists, attending as part of the United States delegation led by the Fish and Wildlife Service Director John Turner, participated in various working groups to redraft resolutions and were active in several key issues including: (1) discussion with the Cat Specialist Group of the World Conservation Union (IUCN) so that an acceptable solution could be developed that reflected the United States' concerns about the proposal to downlist cheetahs; (2) successful opposition of the IUCN Crocodile Specialist Group's support for downlisting the Indonesian population of saltwater crocodiles by recommending strategies for continued export quotas; (3) avoidance of an impasse on a resolution on nursery registration by suggesting an intermediate implementation step; and (4) critical input into revision of the definition of artificial propagation to reduce the risk to wild plants. Office of Scientific Authority staff also worked with delegates from other Parties to modify or clarify listing proposals to arrive at a final version that could be supported by the United States. In particular, discussions with Germany and Guatemala resulted in reducing the number of *Tillandsia* species proposed for listing from 500 to only those 7 bromeliad species needing protection. Although the final approved listing of mahoganies did not satisfy all Parties, the United States proposals for the mahogany and lignum vitae helped establish a precedent for conserving tropical timber species through CITES actions.

Other CITIES Activities

In spring 1991, illegal wildlife trafficking through Grenada, West Indies, drew the attention of the international conservation community, including the CITES Secretariat. Although they are not a Party to CITES, the Government of Grenada took action to halt trans-shipment of smuggled animals (primarily birds) through their country by seizing all remaining animals. In response to requests from the CITES Secretariat, the Government of Grenada, and nongovernmental agencies, a biologist from the Office of Scientific Authority inspected animals and facilities in Grenada and assisted in developing husbandry protocols for care of the animals while in custody of the Grenadian government. The biologist also recommended options for disposition of the animals that would conform to CITES policies regarding confiscated wildlife.

During September 1991, a representative from the Office of Scientific Authority was part of a United States delegation that visited the People's Republic of China to discuss and compare implementation of CITES in the United States and People's Republic of China. This visit was conducted under the United States–People's Republic of China Nature Conservation Protocol of 1986 and included visits to the Chinese port cities of Guangzhou, Shanghai, Tianjin, and Beijing, as well as to two wildlife and plant rescue centers for confiscated specimens.

Office of Scientific Authority staff also participated in meetings of the CITES Animals, Plants, and Nomenclature committees held in foreign countries. Biologists from Office of Scientific Authority especially supported efforts to clarify taxa protected by CITES, enhance the role of Scientific Authorities, promote proper studies of animals traded in significantly large numbers to determine the effects of trade on those species, and expand implementation provisions for plants. Office of Scientific Authority biologists also participated in revision of key resolutions developed by the CITES committees. An Office of Scientific Authority botanist, after serving 7 years as Chairman of the Plants Committee, turned over the Chair to the Australian delegate and was elected Vice Chairman of the Plants Committee at the 1992 CITES Conference in Japan.

Panda Import Guidelines

On 14 March 1991, the Fish and Wildlife Service published guidelines for the importation of giant pandas. These guidelines were developed by the Office of Scientific Authority, in conjunction with the Office of Management Authority, to ensure that imports of giant pandas for captive breeding or temporary exhibition loans to zoos directly or indirectly enhance the survival of the species. The policy restricts the age of animals imported for temporary exhibition loans to give consideration only to those animals too young, too old, or otherwise incapable of reproducing, or under special circumstances, older animals that already have living offspring.

Other aspects of the policy include requirements for providing suitable facilities and care for pandas, prior registry of animals intended for import (i.e., in a studbook or similar document), and identification of specific conservation projects to be funded by proceeds from the exhibition of the pandas.

Conservation of the giant panda is a high priority of the People's Republic of China and the world conservation community, and is strongly supported by the United States. Fewer than 1,000 pandas are believed to remain in small, fragmented populations in the wild. Poaching and habitat loss are persistent threats to panda survival in the wild. Fewer than 100 giant pandas are in captivity, and breeding programs have not yet achieved a birth-rate that is self-sustaining.

International Cooperation

International Efforts in Conserving Biological Diversity

Over the past decade, concern about biological diversity (how many different kinds of plants and animals occur within a defined area) has increased, largely because of the threatened reduction of diversity on a global scale. Maintenance of biological diversity, even on a local scale, is clearly an international problem. For example, the causes of habitat degradation in any area are not always locally generated. Air and water pollution move easily across international boundaries, and biological pests ride from country to country on contaminated agricultural or other products. At the same time, many species comprising the biological diversity a country wishes to conserve naturally move across international boundaries as a part of their normal activities. In the United States, these include insects and representatives of most groups of vertebrates including salmonids, marine turtles, marine mammals, and migratory birds. More than 50% of the about 650 species of birds that breed in the United States winter in countries to the south. Alone, they represent nearly one-quarter of the vertebrate (excluding fishes) biodiversity of the United States. Clearly, programs for the preservation of biodiversity must deal with the maintenance of migratory species year-round, in all parts of their ranges.

The major international threat to biodiversity in the United States is loss of habitat at home and abroad. Therefore, protection of undisturbed habitats must be a priority in programs dealing with the biodiversity of the United States. For protection to be successful, the effort must have strong support from local residents and government because habitat protection often has political and economic ramifications.

The Fish and Wildlife Service is helping in this international effort through cooperative research on habitats and species. The Service also works with local residents in countries south of the United States to develop protection and management activities that benefit the residents. Currently, scientists from the Biological Survey Project of the National Ecology Research Center are cooperating with colleagues on studies of frogs and birds in Peru, mammals and frogs in Venezuela, plants and birds in Mexico, and reptiles on Ecuador's Galapagos Islands. Cooperative international efforts to wisely manage these habitats can only enhance the status of species that spend part of their lives in the United States.

Amphibian Biological Diversity

Concerned with the significant worldwide loss of biodiversity through habitat destruction, especially of tropical forests, scientists from the National Museum of Natural History, the Biological Survey Project of the National Ecology Research Center, and the BIOLAT Biodiversity Program of the Smithsonian Institution recently organized a project to develop a series of manuals advocat-

ing standardized sampling methods for biodiversity.

Amphibians were selected as subjects for the first volume in the series. Many species are wide-ranging and could be used as indicators of broad geographic or global changes in the environment. Others are habitat specialists with restricted distributions and could signal changes on a more local level. Certain physiological (e.g., permeable skin) and ecological characteristics (e.g., complex, bi-phasic life cycle) make amphibians potentially excellent indicators of environmental health. At present, no single reference describes techniques for monitoring or inventorying amphibians, nor the circumstances where each is appropriate.

To fill this void, scientists working on this cooperative project prepared a manual that emphasizes the inventory and monitoring of assemblages of amphibians, provides guidelines, and describes sampling protocols for the study of amphibian populations. They recommended standard techniques to inventory and monitor amphibian populations, to provide a basis for obtaining quantitative data important to understanding amphibian biodiversity, to establish long-term baseline data, to evaluate the status of amphibian populations throughout the world, and potentially to detect declines as part of any global change. Adoption of these recommendations will ensure comparability between sites, at least within large areas of similar vegetation and animals (biomes), and lead toward greater understanding of amphibian species diversity in particular and biological diversity in general.

Herpetofaunal Diversity in the Bahamas

Biologists from the National Ecology Research Center–Gainesville field station assisted biologists from the University of Florida in conducting surveys of the amphibian and reptile biodiversity in the Exuma Cays Land and Sea Park in the Bahamas. The survey was undertaken at the request of the Bahamas National Trust. Eleven islands were visited in 10 days, resulting in numerous new island records. Bells Cay in particular contains a rich herpetofauna and tropical hardwood forest, in addition to important historical ruins dating from the Loyalist Period (late 1700's). The acquisition of this island by the Bahamas National Trust would be a significant step in protecting Exuma's flora and fauna. Two small introduced populations of land iguanas, under Federal protection by the United States, were found to be maintaining their numbers.

Biological studies were begun on the life history of the Bahama's curly-tail lizard; 37 were marked and 11 were trailed by using fluorescent pigments to determine spacing and movement patterns. Researchers visited several caves to determine if fossils were present. Although none was found, large populations of wall geckos were discovered. The survey supplied park personnel with important new distribution data that should assist in future management and recommendations for acquisition.

Cooperative Research on Habitat Restoration in the Upper Mississippi and Volga Rivers

Scientists with the National Fisheries Research Center–La Crosse and the Institute of Biology of Inland Waters in Borok, Russia, are comparing approaches for improving degraded habitats for fish in the upper Mississippi and Volga rivers. In 1991, three Russian specialists participated in the Finger Lakes Project, a habitat-rehabilitation project intended to improve conditions for fish in six connected backwater lakes in Pool 5 of the upper Mississippi River. The primary management objective of the Finger Lakes Project was to provide water temperature, dissolved oxygen concentration, and current velocity in winter that were suitable for sportfishes. The lakes were being altered hydrologically to achieve such conditions. On the Volga River, a habitat-rehabilitation project on the eastern shore of the Rybinsk Reservoir was planned by scientists from La Crosse and Borok, and a data base on the preproject hydrology and biota of the site was gathered. Results from these studies will provide guidance for other habitat-rehabilitation projects in large temperate rivers.

Cooperative Studies of Sea Otter Habitat in Russia

In September 1991, sea otter biologists from the Fish and Wildlife Service, other United States institutions, and Russia, met in Petropavlovsk-Kamchatski, Russia, to exchange information on the biology and conservation of sea otters and their habitats throughout the northern coastal regions of the Pacific Rim. Discussion topics included a recent mass die-off of sea otters in the Commander Islands. Although data were not conclusive, evidence suggests that most deaths resulted from populations growing beyond local carrying capacity. Meeting participants agreed that additional data on sea otter habitat would be useful in understanding and modeling apparent instabilities in the Commander Islands sea otter population.

The Academy of Sciences of Russia invited Fish and Wildlife Service biologists to work with

Biologist emerges from a cave on Waderick Wells Cay with geckos captured during surveys of herpetofaunal biodiversity in the Exuma Islands, Bahamas.

Russian sea otter experts during summer 1992 to evaluate food supply and other characteristics of sea otter habitat of the Commander Islands. A better understanding of sea otter population dynamics and habitat relations in Russia will help improve our understanding of population/habitat relations for sea otters in the United States and contribute to the development of more effective strategies for conservation and management of the species.

Russian Cooperation Vital to Pacific Walrus Efforts

The Pacific walrus population is shared with Russia; nearly two-thirds of all Pacific walruses counted during the 1985, 5-year United States and Russia cooperative survey were in Russian waters. Researchers at the Alaska Fish and Wildlife Research Center began research in 1986 to study walrus population dynamics. The work focused on ways to increase the accuracy and precision of the methods used to document population status and to adapt satellite telemetry technology to collect behavioral information and document walrus movements and population bounds. Included was an evaluation of the utility of adaptive sampling techniques, videography, 35-mm photography, and line transects for assessing populations.

Cooperation with Russian colleagues is vital to the success of the research program. Fish and Wildlife Service biologists have maintained active exchanges with personnel at the All-Union Fisheries and Oceanography Research Institute (VNIRO) and the Pacific Fisheries and Oceanography Research Institute (TINRO) in Magadan. In 1987, scientists participated in a 6-week cruise to the Chukchi Sea aboard a Russian ship. In 1988, two Russians came to Alaska for several weeks and helped attach the first satellite transmitter to a female walrus. For 4 weeks in 1989, two Russians took part in attaching radio transmitters, trials with videography, and discussions of survey strategies for a 5-year cooperative survey. Later that same summer, a group of United States scientists, including one from the Alaska Fish and Wildlife Research Center, traveled to Rudder Spit in Russia to deploy satellite transmitters on walruses. In 1990, the Alaska Region commissioned the 1990 5-year cooperative walrus survey using the protocol proposed by the Alaska Center researchers and Center cooperators from the University of Maine. In May 1991, three United States scientists joined four Russian colleagues aboard the Russian marine mammal harvest vessel, *ZRS Zaslonovo*, for a pinniped research cruise. The Center's walrus biologist, one of the three United States scientists, was cruise leader. Researchers placed satellite transmitters on seven adult female walruses, and tagged one male with a conventional VHF radio transmitter. They also made incidental observations of marine mammals and birds, weather, and ice.

Collaborative Wildlife Health Investigations Initiated in Russia

Russia was a major focus for the National Wildlife Health Research Center as well as other Research and Development entities. Major die-offs of wildlife in Russia resulted in the initial development of the Center of Wild Animal Ecological Pathology and Epizootiology as a component of the Russian Academy of Science. Site visits by teams of scientist from both centers were made to the Caspian Sea, Russian Steppes, and Taimyr Peninsula to become familiar with wildlife health programs involving migratory birds, Caspian seals, saiga antelope, and reindeer.

A major die-off of black-headed gulls, Caspian terns, and other birds was encountered on the first of two trips to Zemchurzny Island in the Caspian Sea. That island and Koali Island were selected as sites for field collections of samples from Caspian seals. Collections made during the second trip initiated collaborative efforts to determine causes for high mortality, poor body condition, and poor reproductive performance of Caspian seals. The National Marine Mammal Laboratory is helping to process the specimens collected. A separate investigation involved collecting of more than 100 blood samples from about 500 wild reindeer being processed for meat on the Taimyr Peninsula in Siberia. Twenty-two of the samples tested positive for an antibody to the bacterium that causes brucellosis. Epidemiological information from the Ministry of Agriculture indicates anthrax has been recurring in domestic reindeer in the Taimyr region since the early 1900's, but has not yet been reported in wild herds. The close association of wild and domestic reindeer in some areas makes control of this disease imperative in domestic herds.

Polar Bears: a Shared Resource with Russia

Polar bears are found in northwestern and arctic Alaska during winter each year. Native Alaskan hunters harvest them along the northwestern Alaska coastline for subsistence. Biologists from the Alaska Fish and Wildlife Research Center found that these wintering polar bears spend much of their lives in waters adjacent to the Chukotski Peninsula in northeastern Russia. A cooperative research program was established with Russia to learn more about the ecology of polar bears of the Bering and Chukchi seas.

The first phase began in April 1989, when Russian biologists visited the Center's research project at Barrow. The second phase occurred during spring 1990, when three Fish and Wildlife Service biologists spent 6 weeks with their Russian colleagues capturing and collaring polar bears on Wrangel Island and along the northern coast of the Chukotski Peninsula in the Russian arctic.

Wrangel Island is unique because female polar bears congregate there before entering maternity dens. Between 300 and 600 females den each year on Wrangel, one of the highest known densities of polar bear dens in the world. Polar bears in western Alaska den on Wrangel and Herald islands and the northern coast of the Chukotski Peninsula. Only female polar bears that will have cubs enter the over-winter dens; all others remain active throughout the winter.

Fish and Wildlife Service biologists placed satellite telemetry collars on females that den on the two Russian islands and off the western coast of Alaska. Biologists expect to answer questions about movements, distribution, and population dynamics of polar bears in the Chukchi Sea from data gathered by satellite. The origin of bears denning on Wrangel Island is important for determining population size, dynamics, and status; for determining the size of the allowable harvest of polar bears in the Chukchi and Bering seas; and for allocating the harvest between the two countries. In 1991, Fish and Wildlife Service biologists captured 61 bears and placed satellite telemetry collars on 22 adult females. Twenty of those adults, accompanied by cubs of the year, had recently emerged from dens on Wrangel Island. Biologists saw 40 sows with litters during the capture program. Three of the litters had three cubs each, a rare occurrence among polar bears. Average litter size approximated two cubs. In 1992, biologists captured 74 bears and placed satellite telemetry collars on 26 adult females. One sow captured in 1992 had four cubs.

Scientific Assistance to Russia

A National Wildlife Health Research Center scientist participated in a 1991 meeting in Petropavlosk, Russia, to assist in evaluating causes of death in Russian sea otters. An estimated 600–700 sea otters died on Bering Island in the Commander Islands during the winter of 1990–91. Mortality on Kuril and other islands was also severe. A plan was developed to monitor mortality and examine carcasses during 1992.

A second Center scientist also participated in the All-Union Meeting on Wildlife Disease held in Moscow, Russia, in November 1991. This scientist provided guidance regarding the organization of wildlife disease activities and research and how the organizational structure might be incorporated into the restructuring and reorganization of the former Soviet republics. The Fish and Wildlife Service sponsored a visitation by a Russian scientist to the National Wildlife Health Research Center during summer 1992 to develop collaborative investigations that would address disease problems in migratory birds, saiga antelope, and other species of concern.

Barro Colorado Island Bat Study

A recent publication (Smithsonian Contributions to Zoology, No. 511) documents one of the most extensive and comprehensive bat studies to date. Fish and Wildlife Service and Smithsonian scientists and collaborators captured, marked, examined, and released many bats representative of the 56 species of bats on Barro Colorado Island. They marked 8,907 common fruit bats that were captured a total of 15,728 times. In addition to detailed information on physiology, movements, reproduction, longevity, food habits, and population dynamics, several innovative study methods new to bat biology evolved during the study. Some of these innovations included marking bats with a bat band strung on a bead-chain necklace, daily surveys for evidence of feeding activity to locate netting sites for maximum captures, the use of bird calls and screeching bats to attract bats to the nets, objective criteria for aging and assessing reproductive condition (developed with captives studied at the National Zoological Park), and methods for analyzing fidelity to core activity areas.

Latin American Library Assistance Program

A critical problem facing the world today is the rapid and unplanned degradation of habitats resulting from population growth, agricultural practices, and industrial expansion. Habitat loss is particularly significant in Latin American, where the loss can have potentially devastating effects on populations of wintering Nearctic migratory birds, as well as on biodiversity in general.

Although interest in habitat degradation is intense and increasing in fully developed countries, successful programs of habitat protection and sustainable resource use in developing countries must be designed and operated locally. Thus, it is critical that resource managers, ecologists, and environmentalists in these countries have access to the resources necessary to do the job. Particularly critical is access to the literature of their fields.

Scientists at the National Ecology Research Center are participating in a cooperative venture with the University of Kansas and the Council of Biology Editors to enhance holdings of scientific litera-

Puerto Rican biologists and a young enthusiast assisting a biologist from Patuxent Wildlife Research Center in the capture and marking of nongame migratory birds. *Photo by C. Robbins.*

ture in Latin American research natural history libraries. Journals and other publications donated by North American professional scientific societies and institutions are being distributed to 75 university, museum, and government libraries throughout Latin America.

This program, which has received financial support from numerous foundations and other institutions, is an example of cooperation between the public and private sector to achieve an important conservation and wildlife management goal.

Mexican Students and Guatemalan and Pakistani Biologists Trained

Patuxent Wildlife Research Center biologists continued their migratory bird research and training activities in southern Mexico and Central America. Biologists provided training in identifying birds captured in mist nets and for handling birds, methods of banding, and techniques for determining age and sex of birds. The trainees were Mexican students and biologists from several Guatemalan conservation organizations. Associated with this work, Center scientists gave talks on their neotropical research to students from the University of Merida and the Valley University in Guatemala. Center scientists continued their collaborative research efforts with Mexican biologists on habitat-use patterns of wintering neotropical migrant birds in eastern Mexico.

Patuxent researchers, with the assistance of staff from the Northeast Region and the Office of Migratory Bird Management, provided a 5-week training course for two biologists from the Pakistan Zoological Survey. Training involved demonstration of capture and marking techniques for migratory birds, analysis of shorebird count data, an overview of migratory bird research and management in the United States, wetland habitat classification, and computer application.

United States–India Wildlife Health Program Continues

As part of the second Wildlife Health component of the Fish and Wildlife Service–Wildlife Institute of India collaborative project, the National Wildlife Health Research Center personnel presented a workshop in Kahnha National Park on wildlife immobilization. The week-long program was directed toward field officers of State forest services, and included both lectures and hands-on laboratory sessions. Assistance was also provided to ongoing research on the transmission of diseases between wild and domestic animals within and around India's national parks. Personnel from the National Wildlife Health Research Center also participated in an International Symposium on Diseases in Captive and Wild Animals held in Bangalore, Karnataka, by presenting papers, serving as chairpersons for scientific sessions, and developing recommendations for enhanced collaboration and integration of efforts concerning wildlife health by the veterinary and wildlife management professionals of India. These recommendations were adopted by the veterinary groups sponsoring the meeting.

The Sri Lanka Department of Wildlife Conservation received 3 weeks of classroom and field exercises from personnel of the National Wetlands Research Center. Trainees developed monitoring plans for wetlands in their home regions as one phase of their training. *Photo by J. Keough.*

Lead Poisoning in Waterfowl Receives International Attention

More than 100 participants from 21 countries met in Brussels, Belgium, in June 1991 at a functional workshop to review the extent of lead poisoning throughout the world and to identify possible solutions. Participants included experts on lead poisoning, government agency representatives, conservation and hunting organization representatives, and arms and ammunition manufacturer representatives. The meeting was organized by the International Waterfowl and Wetlands Research Bureau in the United Kingdom. Lead poisoning of birds other than waterfowl was assigned as the presentation topic by the National Wildlife Health Research Center. Data were presented on lead poisoning from ingestion of lead shot for 31 species of free-ranging birds other than waterfowl.

Persian Gulf War Heightens Wildlife Concerns

A National Wildlife Health Research Center scientist traveled to Bahrain at the invitation of the United National Educational, Scientific, and Cultural Organization (UNESCO), as one of a six-member team to present a "Workshop on the Rehabilitation of Oil Contaminated Animals" to representatives of five Persian Gulf States. The 5-day workshop provided training on how to plan, organize, and respond to oil spills jeopardizing wildlife. Scientists provided techniques for dispersing unaffected animals; retrieving, cleaning, and rehabilitating oiled wildlife; and protecting sensitive areas from oil impact.

International Wetlands Preservation Workshops

The National Wetlands Research Center, in coordination with the Office of International Affairs, assisted two foreign countries by conducting workshops designed to provide training in identification, classification, and monitoring of wetland ecosystems. In August 1991, the National Wetlands Research Center assisted the Mexican government by training governmental and university staff in Tamaulipas, Mexico. This workshop began with problem-solving sessions that presented a development scenario and courses of action that could be taken to reduce effects on wetlands. Following the workshop were field investigations in the Lower Laguna Marsh to train Mexican nationals in basic techniques used to examine factors affecting wetland plant communities. Participants spent the final 2 days of the workshop discussing findings, writing reports, and presenting management alternatives.

During September 1991, the National Wetlands Research Center assisted the Sri Lanka Department of Wildlife Conservation in a more comprehensive training program that involved 3 weeks of classroom and field exercises in Sri Lanka. The purpose of the workshop, conducted in partnership with the Asian Wetlands Bureau, was to train participants in wetland function and assessment techniques. During the second week, participants conducted field assessments of several wetlands on national park lands. The trainees developed monitoring plans for wetlands in their home regions.

Wildlife

"VISION for the future"
Goal: To restore, enhance, manage, and protect a healthy diversity and desired distribution of wildlife species and their habitats.

Research and Development scientists have increased efforts to gather data on nongame migratory birds and their essential habitats. Biodiversity, corridors, fragments, declining habitats, and linking habitats called for an increase in the use of GIS in support of research and application processes. New techniques of population assessment have been applied within the Fish and Wildlife Service and transferred to cooperators for applications to game animals and assessment of pollution health and stability. Evaluation of private lands and habitat restoration programs were undertaken by a number of Fish and Wildlife Service wildlife scientists and ecologists. Scientists at units and centers cooperated with States and conservation organizations to protect and restore resident wildlife. Much effort was expended toward waterfowl and wetland habitat restoration. Data were made available for augmenting information for programs involving urban wildlife, watchable wildlife, and continuing education at all levels.

Wildlife scientists developed many cooperative efforts with our foreign neighbors to the north, south, east, and west. Data are beginning to become available on many species of wildlife that rely on special habitats in more than one country and more than one hemisphere.

The strategies as presented in the *VISIONS* document received much attention by Fish and Wildlife Service scientists. The reports below indicate just a sampling of the information available to aid the Service in meeting the strategies. Additional studies were initiated more recently, but data and reports are not yet available. The effect of *VISIONS* on Research and Development is evident here, but the effect will be more highly visible in future reports.

Mammals

Differences in Denning Dates May Increase the Vulnerability of Female Kodiak Brown Bears

The brown bear population on Kodiak Island is managed by the State of Alaska and Kodiak National Wildlife Refuge personnel. The island population is dense, with an estimated mean density of 1 bear per 4.1 km^2 (1.6 mi^2). Sport hunters harvest about 130 bears (about 4.5% of the population) annually. The number of people visiting the island to view and photograph bears as part of the refuge's Watchable Wildlife program has increased in recent years.

Scientists at the Alaska Fish and Wildlife Research Center have studied survival and productivity of female brown bears. They found that subpopulations living within 70 km (43 mi) of each other had developed noticeably different denning behavior. They located 115 radio-collared bears in 321 dens. In both areas, females entered the den earlier than most males, and pregnant females generally were the earliest to den. In southwestern Kodiak, female bears entered their dens 2–3 weeks later than their counterparts on north central Kodiak Island. The variation may be related to the relative food availability in the two areas in late autumn. Timing of emergence was similar in both areas; males generally emerged first and females with new cubs last. Individual bears exhibited a high degree of fidelity to specific den sites.

The harvest rates and percentage of females in the harvest are affected by the timing of bear hunting. Knowledge of suitable denning habitat and den concentration areas is critical to evaluate potential effects of human activities and developments on the bear population. By close of the fall hunting season (30 November), 77% of the lone females and 98% of the pregnant females in the north central area are in dens. In contrast, only about 40% of the lone females and 70% of the pregnant females in the southwestern area have entered dens by this time. Females and males seem equally vulnerable during the spring hunting season because emergence patterns from dens are similar.

Differences in denning dates may increase the vulnerability of female Kodiak brown bears. The brown bear population on Kodiak Island, Alaska, is one of the densest populations in North America–one bear/4.1 km^2 (1.6 mi^2). There has been a marked increase in the number of people visiting the island to view and photograph bears as part of the Kodiak National Wildlife Refuge's Watchable Wildlife program.

Muskox Population Expands Westward from the Arctic National Wildlife Refuge

Muskoxen are year-round residents of the coastal plain of the Arctic National Wildlife Refuge and would be present each winter when oil and gas exploration drilling and construction activities would occur. Even though winter distribution of muskoxen is not well known, preliminary information obtained using satellite telemetry shows that in winter muskoxen remain in relatively localized areas and reduce activity and movement.

In 1988, biologists from the Alaska Fish and Wildlife Research Center, in cooperation with Arctic National Wildlife Refuge and the Alaska Cooperative Wildlife Research Unit, began an investigation of muskox population parameters, seasonal distribution, movements and activity patterns on and near the Alaska National Wildlife Refuge. Conventional and satellite telemetry are important to the Center's research efforts. The data will assist the Fish and Wildlife Service in determining the potential effects of petroleum exploration and development on muskoxen within the "1002" area, described by the oil industry as the most promising onshore petroleum exploration area in the United States.

Center biologists saw about 500 muskoxen on the coastal plain between the Colville River in north central Alaska and the Firth River in northwestern Canada before to calving in 1989. Canadian biologists saw at least 50 east of the refuge in northwestern Canada in 1989. In April 1990, researchers counted 348 muskoxen on the Alaska National Wildlife Refuge coastal plain between the Canning River and the Canadian border where 359 were seen in 1989. Fish and Wildlife Service biologists also counted an additional 122 muskoxen west of the refuge in April 1990. The portion of the population on the refuge coastal plain before calving have numbered 350 each year during the past 3 years. Population numbers west of the refuge increased rapidly between 1986 and 1987 and again between 1988 and 1989, probably a westward dispersal from the Alaska National Wildlife Refuge.

Caribou Follow the Melting Snow

The coastal plain of the Arctic National Wildlife Refuge in northeastern Alaska is extremely important to the Porcupine Caribou Herd, now numbering more than 178,000 animals. But a portion of the coastal plain, the 1002 area, is equally important to industry for its potential oil production.

The coastal plain of the Arctic National Wildlife Refuge in northeastern Alaska is extremely important to the Porcupine Caribou Herd, now numbering more than 178,000 animals. Annual calving distributions are correlated with the amount of snow cover.

After more than 5 years of research, Fish and Wildlife Service biologists have a better understanding of caribou calving and post-calving activity on the coastal plain. Distributions of caribou at calving are correlated with amount and location of snow cover. In years of late snow melt (1986–88), the number of radio-collared cows that calved in the 1002 area averaged 6.8%. In years when snow melt was earlier (1983–85, 1989–90), the number averaged 57.2%.

Predator protection may be aided by caribou following the mottled background adjacent to the snow line. Post-perinatal mortality of calves from 1983 to 1990 ranged from 0% to 18% and was inversely correlated with the proportion of cows calving in the 1002 area. Post-perinatal calf mortality was higher in years when late snow-melt prevented many cows from calving in the 1002 area. During 1983–85 and 1989–90, when snow-melt was early and many cows calved within the 1002 area, median post-perinatal calf mortality was 9%.

The timing of snow melt influences forage quantity and quality by controlling the initiation of plant growth and phenological development. Calving was not found on the coastal plain in 1988, when snow blanketed the plain during the entire calving period. In 1989, patchy snow cover was present in the historical, concentrated calving area during the peak of calving. The upper foothills to the south were snow-free, while the rest of the coastal plain was snow-covered. Calving was found mainly in the historical, concentrated calving area in 1989 under what is considered the norm for snow distribution. In 1990, the coastal plain was mostly snow-free when calving began, and the caribou did calve on the concentrated area but also further north on the coastal plain. Snow melt pattern and type of vegetation greatly influenced where the Porcupine Caribou Herd calved on the coastal plain.

Mitochondrial DNA Assists in Wildlife Law Enforcement

A common problem in wildlife law enforcement is identifying the species of origin of carcasses, meat, or blood when morphological characters such as hair or bones are not available. Investigators have used immunological and protein electrophoretic procedures for species identification with considerable success. The tests have limitations in distinguishing between closely related species.

Analysis of DNA in tissues provided a potentially powerful tool for species identification. Alaska Fish and Wildlife Research Center biologists, in cooperation with individuals at Montana State University and the Montana Department of Fish, Wildlife, and Parks, refined existing DNA analysis techniques to identify 22 species of large mammals using mitochondrial DNA restriction fragment patterns. The biologists developed a methodology that allows use of tissues previously frozen or slightly degraded. Intraspecific variation was detected in cows, white-tailed deer, mule deer, elk, caribou, grizzly bears, polar bears, and black bears. Mitochondria DNA restriction fragment patterns were reliable species-specific markers useful in forensic investigations.

Marine Mammals: Population Research

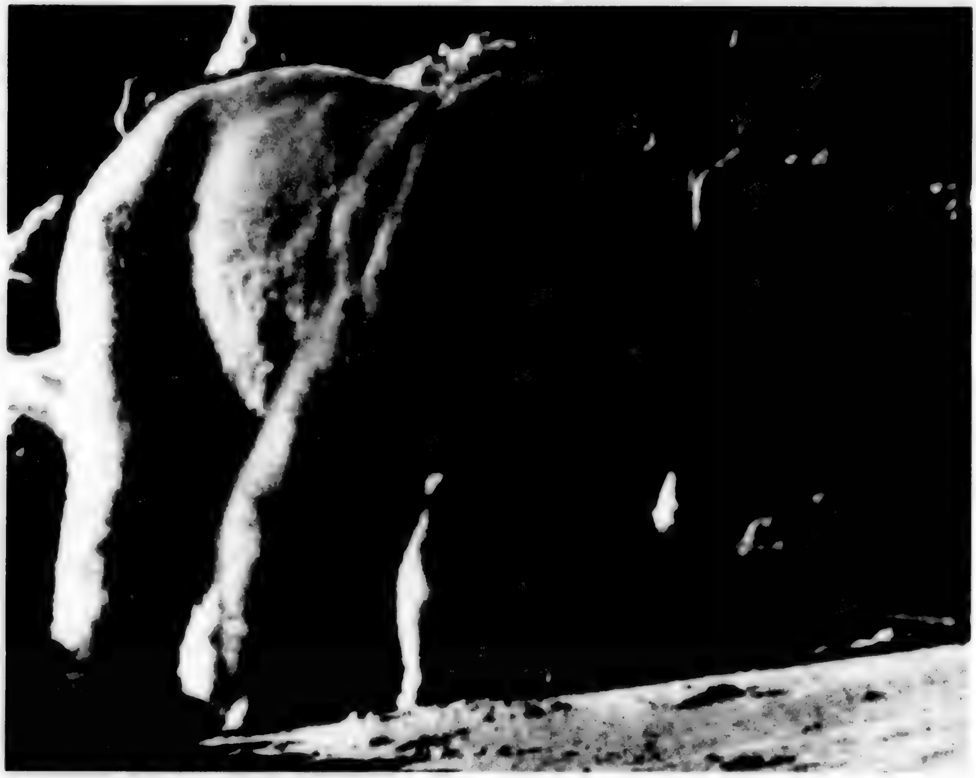
Interactions Between Human Activities and Denning Polar Bears

In 1980, Congress created the 7.7 million-ha Arctic National Wildlife Refuge and designated the 600,000-ha coastal plain "1002" area within the Alaska National Wildlife Refuge for special consideration for oil and gas exploration. Special attention was focused on the 600,000-ha coastal plain "1002" area within the Alaska National Wildlife Refuge for oil and gas exploration.

Female polar bears use the coastal shoreline of the Alaska National Wildlife Refuge for maternity denning. Winter snow dens of females provide a suitable environment for birth and early care of the altricial young. Males generally do not den. Observers have reported den concentration areas in several parts of the world including Wrangel Island in Russia. Little has been known of the distribution of denning among the nearly 1,000 female polar bears inhabiting the Beaufort Sea region.

Between 1981 and 1991, biologists at the Alaska Fish and Wildlife Research Center radio-collared 90 female polar bears in the Beaufort Sea region and followed them to maternity den sites. Thirty five dens were found on land or land-fast ice along the Alaskan and Canadian mainland. Fifteen, or 43% of dens on the mainland of Alaska or western Canada, were within the Alaska National Wildlife Refuge. Eleven dens, or 31% of the 35 dens on the mainland, were within the 1002 area of the Refuge. More polar bears den in the Refuge area than would be expected if dens were distributed evenly across the observed denning range of northern Alaska. Extrapolations of the percentages of collared bears denning on the Alaska National Wildlife Refuge to the estimated Beaufort Sea population suggest that as many as 24 bears may den annually within the boundaries of 1002 and the Alaska National Wildlife Refuge.

The annual recruitment of 5-year-old adult females (age of first



Female polar bears use the coastal shoreline of the Arctic National Wildlife Refuge for maternity denning activity. Forty-three percent of dens on the mainland of Alaska or western Canada were within the Refuge.

breeding) in the polar bear population of the Beaufort Sea region may be as low as 1% of the population. The 24 bears denning on the Refuge are an important component of the bear population of the Beaufort Sea.

Female polar bears in maternity dens may be exposed to low-level aircraft and helicopter flights, oversnow vehicle traffic, and other human activities if petroleum exploration and development occur in the 1002 area. Observations of denned polar bears exposed to aircraft and on-ground disturbances suggest considerable tolerance as well as seasonal and individual variation in their behavioral responses. Female polar bears are more easily disturbed early in the denning period (November and December). Females that are forced to leave a den early can do so with less biological cost. If a female is forced to leave after cubs are born, she must use much energy to locate a new den and keep the young warm and fed. If disturbance by humans must occur, events in October–November are less damaging to denning female polar bears than in January–March. Spatial and temporal restrictions of human activities could minimize exposure of many bears to potentially harmful perturbations. Human activities initiated in October and November could minimize their potential for disruption of critical phases of the denning and reproductive process.

Florida Manatee Population Biology Workshop

The endangered Florida manatee is the focus of considerable attention and concern. Increasing numbers are found dead each year, particularly those killed by boats, and mortality factors and habitat deterioration continue to escalate with the rapid human population increase in Florida. Recovery of manatees is predicated on achieving viable, sustainable populations on both coasts of Florida; reducing or stabilizing mortality; and achieving long-term habitat security. A greater understanding of manatee population biology is required to meet these recovery objectives.

To help distribute knowledge and coordinate effort, a workshop on Florida manatee population biology was held early in 1992 by biologists from the National Ecology Research Center, the Florida Cooperative Fish and Wildlife Research Unit, and the Florida Department of Natural Resources. Objectives were to synthesize information related to manatee population biology, to assess the utility of these data for population models, and to provide directions for future research. Manatee biologists presented papers to about 75 researchers, wildlife managers, academicians, representatives of industry and conservation groups, and an invited group of experts in mammalian population dynamics from various institutions in the United States and abroad. New research directions were established by a number of agencies, and a greater under-

A wild female Florida manatee with twin calves. Data on manatee reproductive attributes were assembled and discussed at a technical workshop on manatee population biology. Manatees produce twins at 1–2% of births. Twinning is very unusual among marine mammals. *Photo by T. O'Shea.*

standing of manatee population processes and their interpretation was reached as a result of the workshop.

Manatee Satellite Telemetry Efforts Expanded

The Fish and Wildlife Service has been tracking manatee movement patterns with satellite telemetry to reveal high-use areas requiring protection. During 1991–92 scientists from the National Ecology Research Center greatly expanded the use of satellite transmitters to track manatees along the east coast of Florida. They assisted the State of Florida in developing satellite telemetry studies of manatees in Tampa Bay, and demonstrated use of the technique to study manatees in Puerto Rico where the population is covered by a separate recovery plan.

Florida manatee location data are transferred to the manatee GIS at the Florida Department of Natural Resources. The State then integrates tracking locations, manatee aerial survey sightings, and mortality records to develop recommendations for boat speed zones, sanctuaries, and coastal development planning. The Florida governor and cabinet have generally approved recommendations for manatee protection for some of the key areas of manatee habitat in Florida, and data are now being gathered for additional regions. The effect of these measures will become evident over the next few years following sign posting, educational efforts, and enforcement activities necessary for effective implementation.

Dugong Status in Palau

Dugongs are found in tropical and subtropical coastal waters of the Indo–Pacific, from Africa east to the Solomon Islands and from India south to northern Australia. The population in Palau, Western Caroline Islands, is one of the few that is found in the vicinity of an isolated archipelago, and the only one under United States jurisdiction.

In cooperation with The Nature Conservancy, biologists from the National Ecology Research Center and the University of Northern Queensland, Australia, completed new aerial and interview surveys of the archipelago in August 1991. Fish and Wildlife Service biologists had previously assessed the status of dugongs at Palau in 1977–78 and 1983 using aerial counts and interviews of local residents. Geographic distribution patterns of dugongs around Palau in 1991 were similar to previous surveys. The 26 counted were slightly less than numbers counted in the 1970's and 1980's. Interviews throughout Palau confirmed that deliberate poaching of dugongs for sport and meat is found regularly. Poaching is a serious threat to the existence of dugongs at this isolated archipelago.

A captive dugong at the Jaya Ancol Aquarium, Jakarta, Indonesia. *Photo by G. Rathbun.*

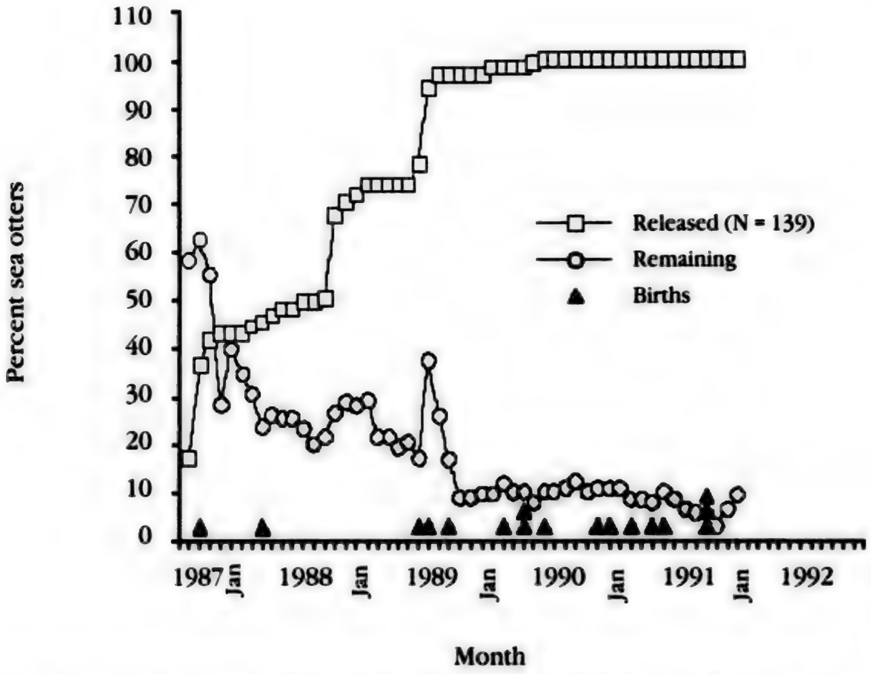
DNA May be Useful in the Zonal Management of Alaska Sea Otters

Sea otters historically are found throughout the North Pacific Rim, from Baja, California, to Hokkaido, Japan. Hunting for furs brought the species close to extinction by the early 19th century. A few remnant populations survived in isolated areas. Since 1911, sea otters have been protected from hunting, and populations in Alaska, California, and Russia have expanded. As sea otter populations expand, management issues assume greater importance. Biologists have proposed zonal management of sea otters facilitated by methods for delineating separable populations. Definition of genetic relations among sea otter populations may provide a basis for effective application of zonal management as well as insight into questions of subspeciation.

Tissue samples were collected from sea otters in California, Alaska, and the Kuril Islands of Russia and were believed representative of the three subspecies. Analysis of DNA revealed each of the three subspecies had different mitochondrial DNA genotypes, although the subspecies are not phylogenetically distinct mitochondrial DNA clades. Variable genotypes also were identified within each of the subspecies. Sequence divergence among genotypes was generally low (less than 2%) and did not vary directly with geographic distance of subspecies designation. Analysis of DNA seemed feasible for differentiating sea otter populations on a geographic scale and could be useful for defining separable zonal management units.

California Sea Otter Population Growing

In the early 1980's, an estimated 80 sea otters per year died in a nearshore, set-net fishery off California. This loss exceeded the estimated population growth rates achieved during the 1930's to the 1970's, and contributed to the lack of growth in the California sea otter population between the mid-1970's and mid-1980's. In 1983, the California Legislature passed legislation to force set-net fishing away from the usual foraging range of sea otters. Based on standardized spring and fall surveys begun in 1982 (fall counts are typically lower than spring counts because kelp canopies are larger and make it more difficult to sight sea otters), the population has increased by about 47% since set-net restrictions began. Current annual growth rates are much lower than those seen in sea otter populations in other areas. Plans are being developed to investigate the disparity between sea otter population growth rates in California and other parts of the species range. A better understanding of this disparity might allow development of additional management practices to improve growth in the California sea otter population, and thereby decrease the time required to reach population recovery.



Sea otter translocations to San Nicolas Island has resulted in a small colony that vacillates between establishment and extinction.

Sea Otter Translocation

In August 1987, biologists at the National Ecology Research Center, in cooperation with the California Department of Fish and Game, began a 5-year project to translocate sea otters from the mainland coast of central California to San Nicolas Island, about 100 km off the southern California coast. According to the Recovery Plan, the objective of the translocation was to create a second, disjunct population of California sea otters to help ensure sea otter survival in the event of a massive oil spill or other environmental disaster along the mainland coast.

By July 1990, Fish and Wildlife Service biologists had moved 139 sea otters to San Nicolas Island. Because of dispersal, deaths, and numerous disappearances of undetermined causes, only about 10% of the sea otters remain at the island. This small nucleus of animals has produced 17 pups, and since November 1989, has fluctuated between 12 and 14 individuals (not including dependent pups).

In July 1991, nearly 4 years after the translocation began, the Fish and Wildlife Service terminated plans to take additional sea otters to San Nicolas Island. Sea otter population growth characteristics at San Nicolas Island have been similar to those seen in other successfully translocated sea otter populations—an initial, dramatic post-release decline, followed by very slow recovery that eventually leads to normal growth and an established population. Even though initial results seem disappointing, research biologists are encouraging patience as the small colony at San Nicolas Island vacillates between establishment and extinction.

Sea Otters and Shellfisheries

Beginning in 1987, biologists from the National Ecology Research Center collaborated with biologists from Fish and Wildlife Service Northwest Region, the University of California, and the California Department of Fish and Game to relocate sea otters to San Nicolas Island, California, and to measure effects of the reintroduced otter population on nearshore marine ecosystems. The investigation focused on effects of otter predation on several species of shellfish used in commercial and recreational fisheries at San Nicolas Island. An environmental impact statement predicted the rapid demise of shellfisheries at the island as a result of otter relocation. Since 1980, National Ecology Research scientists have gathered detailed data on red sea urchins, black abalones, and spiny lobsters at study sites in sea otter habitat of San Nicholas Island. To date, neither the relocated otter population nor ongoing fishery activity has caused significant declines in monitored shellfish stocks at any of the Center study sites. A single black abalone site in an area of frequent recreational harvest by Island residents is the only site that shows reduction from the otters that remained near the island following relocation. Otter predation apparently has not been significant. The otters did consume representatives of all monitored shellfish species. Results to date on San Nicholas Island contrast with conflicts that often develop with shellfisheries as a result of natural range expansion by sea otters. Predator–prey relations that occur with range expansion of naturally-growing otter populations do not seem to provide a good model for predicting effects of relocated sea otters on shellfisheries.

Migratory Waterfowl

Studies of waterfowl conducted by Research and Development contribute to knowledge of population dynamics and habitat needs of the many species of ducks, geese, and swans in North America. Fish and Wildlife Service research also provides the management information needed to more effectively manage the lands and waters that these bird use throughout the year. Waterfowl research is conducted by five research centers: Alaska Fish and Wildlife Research Center, National Wetlands Research Center, National Wildlife Health Research Center, Northern Prairie Wildlife Research Center, and Patuxent Wildlife Research Center. Additional contributions are made by Cooperative Research Units located at major universities.

Changing Agricultural Patterns

Fish and Wildlife Service Research and Development scientists have initiated a number of studies of the consequences of changing agricultural patterns and the resultant effect on the distribution, abundance, and quality of habitat for waterfowl.

Conservation Reserve Program

Farmers in the prairie pothole region contracted with the U.S. Department of Agriculture to take 2.4 million ha of cropland out of production under the Conservation Reserve Program (CRP). Farmers seeded most of this land to mixtures of grasses and legumes. Except during drought emergencies, CRP land is idle for the 10-year life of the contract and may provide significant wildlife benefits. Biologists from Northern Prairie Wildlife Research Center, Jamestown, North Dakota, searched 16 fields (590 ha) of CRP land in the prairie pothole region of Minnesota and North Dakota during 1989–91 to determine nest success of upland-nesting ducks. They searched similar amounts of seeded nesting cover on Waterfowl Production Areas (WPA's) to compare the two covers. Waterfowl nest success on CRP land was higher than on similar covers found on WPA's. Ducks showed great variation in nest success among species and among individual fields. Vegetation had greater height-density on CRP land than on WPA's in Minnesota, but not in North Dakota. Height-density of vegetation on the two covers varied significantly from year to year in Minnesota, but not in North Dakota. Nest success of ducks was not related to vegetation height-density in either state. Gray partridges, ring-necked pheasants, sharp-tailed grouse, northern harriers, American bitterns, and short-eared owls also nested in the cover provided by the CRP, especially in North Dakota. All but the American bittern also nested on WPA's. Biologists detected no significant differences in use of the two covers by gallinaceous game birds or their broods in North Dakota.

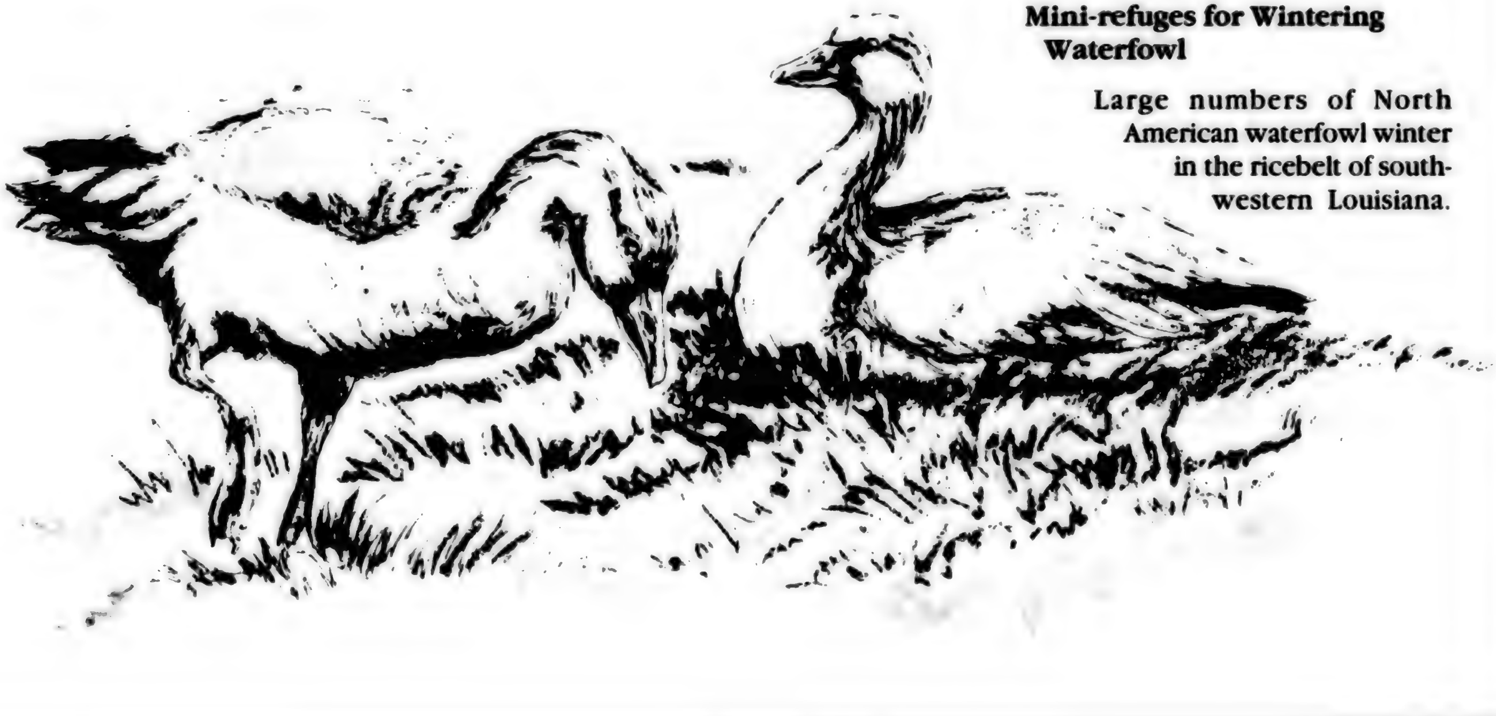
Effect of Haying Practices on Duck Nesting in CRP Fields

During 1989 and 1990, scientists with the South Dakota Cooperative Fish and Wildlife Research Unit evaluated the post-year effects of two haying practices (strips vs. blocks) on duck nesting in Conservation Reserve Program (CRP) fields in five eastern South Dakota counties. Nest densities in idle strips and fields were significantly greater than in hayed strips. Nest densities in idled and hayed blocks were similar but significantly greater than in idled fields.

Daily survival rates of nests in idled strips were significantly lower than in other strips, blocks, or fields. Overall, nest success of ducks in CRP fields averaged 23.4%, but there were treatment differences. The idled strips seemed to attract predators as well as ducks. The conclusion reached was that if haying of CRP or other planted cover is warranted, then cover should not be retained in narrow, idle strips.

Mini-refuges for Wintering Waterfowl

Large numbers of North American waterfowl winter in the ricebelt of southwestern Louisiana.



To provide additional sanctuary areas for birds in this region during the hunting season, the Fish and Wildlife Service initiated mini-refuges by renting and managing ricelands for waterfowl. Biologists with the National Wetlands Research Center studied five tracts of private ricelands (3,087 ha) that were rented and protected from hunting from 1 November 1988 to 1 February 1989.

Aerial and ground surveys led researchers to conclude that daytime refuges where waterfowl can rest without disturbance may be limited in southwestern Louisiana, especially during the hunting season. A provision for tracts of undisturbed, flooded ricelands seems desirable. These areas should be broad and include levies or islands for winter loafing sites. Early flooding of the ricelands (2 weeks before to the hunting season) would allow waterfowl to establish use patterns before the hunting season begins.

Population Dynamics

Biologists at three research centers collaborated in the development of a year-round population model for mid-continental mallards, known as the Mallard Life Cycle Model or Mallard Annual Cycle Model. The Northern Prairie Wildlife Research Center integrated information on spring migration, the breeding season, and the post-breeding period. The Patuxent Wildlife Research Center developed the fall-migration and wintering portions of the model. The National Wildlife Health Research Center contributed estimates of disease mortality. The model is similar in structure to the Mallard Productivity Model developed by the Northern Prairie Wildlife Research Center. It simulates histories of individual females and incorporates changing effects on body mass; nesting and foraging habitat; geographic location; and movement, molting, pairing, reproducing, and death. Researchers can weigh model projections against the required model assumptions before reaching conclusions.

Future research must ascertain additional critical population parameters and functional relations before the model is used for simulated changes in harvest rate or other population projections. Given the limitations, researchers can examine model behavior under a wide range of simulated changes in mortality rates, weather conditions, and wetland conditions. Also, they can examine cross-seasonal effects and multi-year trends.

The model serves as an integrated summary of the state of knowledge of the most important factors affecting the dynamics of mallards in the mid-continent. The model will evolve as a tool for both research and management as we gain more knowledge.

Wood Duck Productivity Model

A productivity model for the wood duck, an important bird in the Atlantic and Mississippi flyways, was developed by the Missouri Cooperative Fish and Wildlife Research Unit. Data for the model were obtained from 30 years of wood duck nest record information obtained on the Duck Creek Wildlife Management Area and Mingo National Wildlife Refuge. Additional input was obtained from published and unpublished data on wood duck reproductive ecology throughout its range. The model is now being used by management personnel to evaluate current management practices and for assessing further research priorities.

Wood Duck Broods in Missouri

The Missouri Cooperative Fish and Wildlife Research Unit conducted a radio telemetry study on Mingo National Wildlife Refuge, which showed that wood duck broods use emergent wetland and scrub–shrub habitats in greater proportion than their availabilities, and that young broods showed a preference for flooded, live forest habitats.

Most broods moved 0–5 km to one of three main brood-rearing wetlands characterized by large (>100 ha) expanses of permanent water, dense emergent vegetative cover (>75%), and good interspersion of scrub–shrub and live forest habitats. Broods usually completed long-distance movements during the 2 days after hatching, and used water travel routes when they were available. Brood survival in Mingo Swamp was about 35% during both field seasons. Early-hatched broods survived better than late-hatched ones in 1988; this pattern was reversed in 1989.

During both years of study, broods of experienced, older females survived better than those of first-time nesters. Water and habitat conditions, weather, and experience of nesting females are factors that contribute to brood-rearing success.

Movement, Survival, and Habitat Use of Locally Fledged Juvenile Wood Ducks in Ohio

Scientists at the Ohio Cooperative Fish and Wildlife Research Unit used radio telemetry to ascertain movement patterns, survival, and habitat use of locally-fledged, juvenile wood ducks between fledging and migration. Juveniles were fitted with radio transmitters and tracked in 1989 (18 females, 11 males) and 1990 (13 females, 19 males). Weekly distance moved from the natal marsh increased at the rate of 0.20 km per week during premigration and reached 4.7 km by the 14th week after fledging; males moved significantly farther.

Most activity before mid-September was a shuffling between roosts and feeding areas near the natal marsh. The Kaplan–Meier estimate of survival of 32 juveniles in the 16 weeks between fledging and migration was 0.679 ± 0.0907. The Mayfield survival estimate (2,590 exposure days) was 0.5887. All pre-migration mortality was from hunting. Riverine emergent wetlands and palustrine scrub–shrub habitats were the most used habitat types in diurnal periods. At night, palustrine scrub–shrub habitats dominated by buttonbush were most preferred.

Mallard Wintering Ecology

A study by researchers of the Missouri Cooperative Fish and Wildlife Research Unit to evaluate aspects of late-wintering ecology of female mallards in Arkansas was recently completed. Radio transmitters were used to follow individual birds; none died during the 2,765 exposure days in 1988 and 1989. Nonetheless, the scientists could calculate point and interval survival rates based on the binomial distribution. The point estimate for daily survival in late winter was 0.9997 and that translated into a 30-day interval survival rate of 0.991. Habitat use depended strongly on year ($P < 0.0001$), capture site ($P < 0.001$), and date ($P < 0.0014$). These correlations were related to differences in habitat composition at the two trap sites and to the precipitation patterns encountered during each field season. Habitat use was not directly dependent on age or condition of the female, but it was dependent on molt. Movements of female mallards varied by year, trap site, and date and were related to precipitation patterns during winter, as well as habitat composition at the two study sites.

Wintering Redheads in Texas

Patuxent Wildlife Research Center biologists conducted investigations to determine whether the abundance of shoalgrass was limiting numbers of wintering redheads in the Laguna Madre of Texas. Ducks were regularly seen (>95%) above shoalgrass meadows, their favored food. Duck exclusion studies showed that redheads consumed up to 75% of the shoalgrass rhizome biomass, and that redhead use declined after rhizome biomass reached 10 g/m^2. Results suggest that the decline in number of wintering redheads in the Laguna Madre is a result of limited shoalgrass. Further reduction in redheads will likely occur if shoalgrass continues to decline in the Laguna Madre.

Wintering Redheads in Louisiana

The estuarine waters of the Chandeleur Islands in Louisiana provide a traditional wintering area for about 20,000 redheads, the third largest concentration of wintering redheads in the Gulf. Food habits were examined by looking at 287 gastrointestinal tracts to learn what attracted the large numbers of redheads. Plant material, largely shoalgrass, was 83% of the esophagi contents during the winters of 1987–88 and 1988–89. Proventricular contents were similar in the amount of plant material, but contained a higher proportion of animal matter (33%). Adult females and males consumed more animal food in later winter than in early or midwinter, but juveniles showed no seasonal trend. Late winter increases in animal foods may reflect preparation for migration and reproduction.

Surprisingly, in a second study, adult females and males showed a significant increase in total body fat from early winter to mid- and late winter. Juvenile males showed an increase in body fat in all three seasons; juvenile females exhibited a significant increase only in late winter. Consistent increases in body fat among all ages and sexes of wintering waterfowl have heretofore been unknown. Relations between winter climate, latitude, and lipid deposition remain unclear. Further studies will provide a better understanding of winter bioenergetics and their significance in waterfowl management.

Wintering Canvasbacks on the East Coast

The distribution of females and males in local and regional wintering waterfowl populations can be an important consideration in future harvest strategies. Patuxent Wildlife Research Center biologists investigated seasonal flock size and sex ratio characteristics of canvasbacks wintering from the Chesapeake Bay of Maryland south to coastal North Carolina. Monthly aerial photographic surveys from December 1986 through March 1987 yielded usable imagery of 842 flocks totalling 194,664 canvasbacks.

Center scientists found significantly more females in North Carolina than farther north, so special regulations might protect females in this region if hunting of canvasbacks in the Atlantic Flyway were allowed. Conversely, a harvest emphasizing males might best be accomplished at more northern latitudes, such as Chesapeake Bay. In addition, biologists found that females tended to be found in greater relative numbers in small flocks, and males in large, offshore flocks. Harvest regulations designed to focus on males should emphasize hunting access to large, offshore flocks, rather than to flocks on small, protected waters or at near-shore locations that may be exposed to greater hunting pressure.

Wintering Mallards in Mississippi

In recent years, the Fish and Wildlife Service has increased efforts to study the ecology of waterfowl in winter, especially the survival rates and habitat use of females. Previous studies of mallards in the Mississippi Alluvial Valley indicated that adult females survived at a higher rate (84%) than immature females (70%) and that hunting was a primary source of mortality of both age classes.

A follow-up study was conducted by Patuxent Wildlife Research Center biologists in cooperation with scientists from the University of Missouri. An additional 88 female mallards (45 adults and 43 immatures) were radiomarked to estimate survival rates in late winter after the hunting season. None of the marked females died during the study, strengthening earlier conclusions that natural mortality of mallards wintering in the Mississippi Alluvial Valley is relatively low. Analyses of habitat use by females indicated that choice of habitats was influenced more by habitat availability than by characteristics of individuals such as age, molt status, or physical condition.

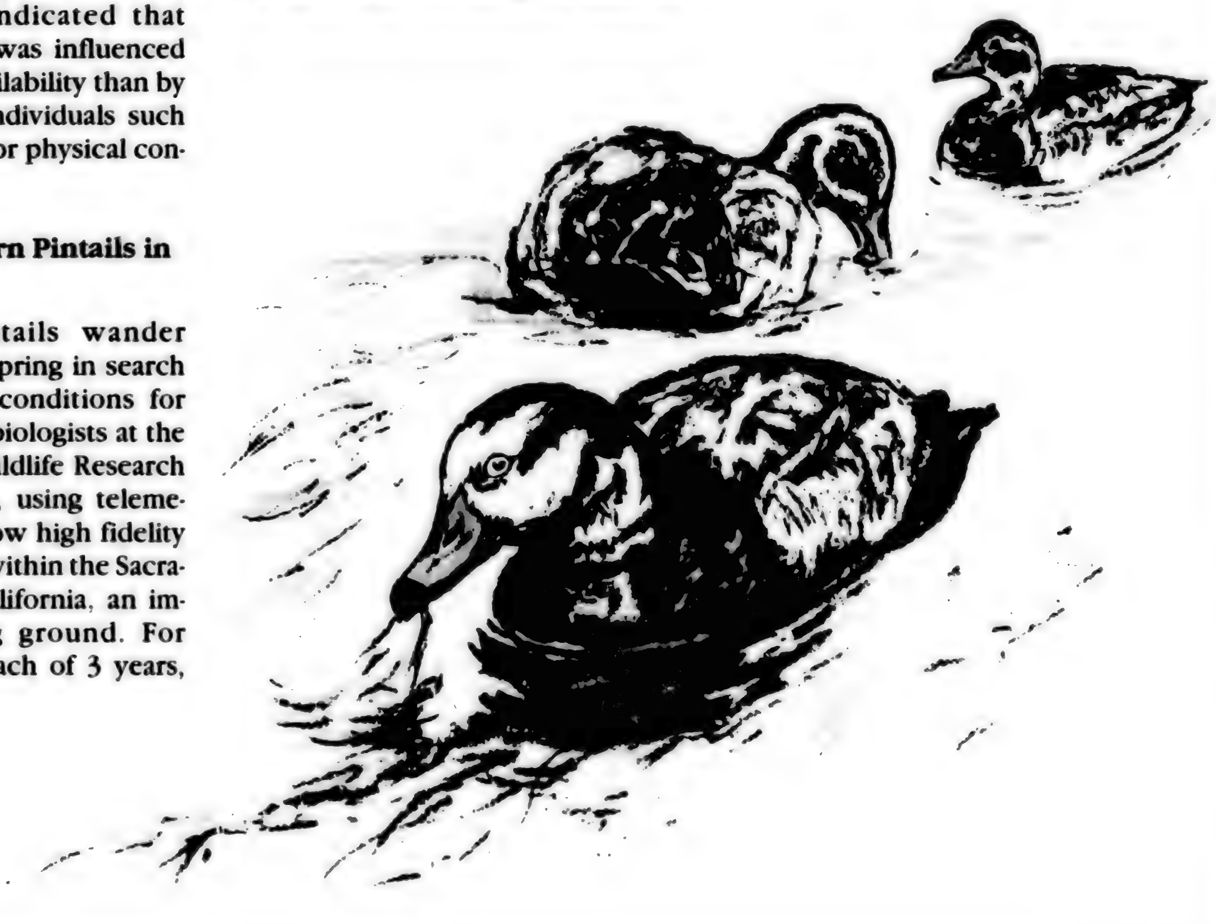
Wintering Northern Pintails in California

Northern pintails wander widely during the spring in search of suitable water conditions for nesting. However, biologists at the Northern Prairie Wildlife Research Center have found, using telemetry, that pintails show high fidelity to specific regions within the Sacramento Valley in California, an important wintering ground. For 6 months during each of 3 years, biologists followed the daily movements of adult female pintails and found that 90% of the use-days occurred in the Sacramento Valley. These data suggest that a subpopulation of pintails is present in the Sacramento Valley that has nesting and staging areas that differ from wintering populations elsewhere in California.

Alternatively, as the Pacific Flyway population of pintails has declined, the largest proportion of the remaining birds may have moved to the Sacramento Valley. Continued study of these wintering pintails on the major California wintering areas will improve understanding of movements of wintering pintails and the relevance of use areas to subpopulations.

Northern Pintail Numbers and Survival

Continental populations of northern pintails remain at all time low levels. Biologists from Northern Prairie Wildlife Research Center used radio telemetry to estimate survival rates for adult female northern pintails in the Sacramento Valley in California. During three late summer through winter seasons (1987–90), the probability of a pintail surviving a given day before, during, and after hunting season was not significantly different within or among years, but causes of mortality differed in each period. Avian and mammalian predation and disease (avian botulism) accounted for preseason mortality; hunting was the major mortality factor during the hunting season; and disease (avian cholera), illegal kills by humans, and unknown causes accounted for postseason mortality. The average August through February survival rate was 89%, higher than reported for other ducks, and suggests that if mortality is contributing to population declines, management should be directed to periods other than winter for this population of adult pintails.



Regional Differences in Waterfowl Parameters

Waterfowl managers need to know whether regional differences in predation rates, land use, or harvest pressures affect waterfowl population parameters. Recoveries of mallards banded by cooperators during 1962–70 and 1979–84 were analyzed by biologists at Patuxent Wildlife Research Center to determine if survival or recovery rates varied from north to south. The north to south variation was predicted by the hypothesis that the birds that migrated the greatest distance should have decreased survival rates because of the additional stress associated with the longer movement.

Results indicated that survival decreased from north (about 70%) to south (about 60%) in each time period. Recovery rates, and presumably hunting mortality, exhibited little variation with latitude. Habitat alterations that have reduced recruitment rates of ducks nesting in intensively farmed areas of the prairie potholes in recent years might also be responsible for the north–south cline in survival rates.

Predator Communities in the Prairie Pothole Region

Predation is the major cause of low duck recruitment in the 777,000 km^2 prairie pothole region of Canada and the United States. Surveys were developed and conducted by scientists of the Northern Prairie Wildlife Research Center to determine the species composition and abundance of predators affecting ducks throughout the Region. The surveys showed that nesting ducks at each of 33 scattered study locations were exposed to 8–14 mammalian and avian predator species, 4–9 of which were common or numerous. Predator species composition and abundance varied greatly among locations. For example, in south-central Alberta coyotes and American crows were numerous but red foxes and raccoon were scarce, whereas the reverse was true for eastern North and South Dakota. Examination of historical and recent records revealed that, following settlement of the Region by Europeans in the late 1800's, predator communities throughout the Region have undergone both gradual and abrupt changes from habitat alterations, direct human effects on predators, and interspecific relations among predators.

A female mallard marked with a radio-transmitter to determine daily survival rates and sources of mortality during winter in the Mississippi Alluvial Valley.

Early Survival of Young Mallards

An intensive banding effort in Saskatchewan during 1956–59 provided 3,670 recoveries for estimating survival of juvenile mallards during the period between the flightless (Class II or III) and flying immature stages. Patuxent Wildlife Research Center scientists found that survival rates of juvenile males and females during July–September were similar and averaged 84%. Estimates of survival from the local flightless to immature stages fill a void in our understanding of mallard population dynamics and underscore the need for better information about factors affecting the survival of ducklings from hatching until just before flight.

Lesser Snow Geese Nesting in the Arctic

Scientists at the Alaska Fish and Wildlife Research Center initiated a cooperative research program in 1988 to evaluate some of the potential problems that might be associated with development of oil and gas resources on the Arctic National Wildlife Refuge. Lesser snow geese concentrate before migration in the Arctic National Wildlife Refuge, part of a larger staging area that extends along the Arctic coastal plain into Canada. These geese increase fat reserves by as much as 400% while on the Arctic National Wildlife Refuge. Snow geese are extremely susceptible to disturbance by aircraft. Aircraft commonly associated with petroleum development in the Arctic could disrupt feeding, displace geese from feeding habitats, and alter the size of premigratory fat reserves.

Studies of goose food habits showed that the most suitable habitats for feeding comprised only 11% of the available habitats on the coastal plain. Goose feeding is further constrained by physiological limits to gut capacity and forage passage rate. Because of their low digestive efficiency, geese must consume large amounts of forage, up to 25% of their body mass daily. The high intake causes geese to feed for long periods each day. Unfortunately, they cannot increase forage rates to compensate for foraging opportunities lost to disturbance. Feeding for a greater number of hours each day is the only opportunity available.

It may not be physiologically possible for some individuals to spend more time feeding. Snow geese displaced from the coastal plain by disturbance may not be able to locate suitable feeding habitat in other portions of the staging area. Disturbances to feeding by any cause, including oil and gas development, would have a negative affect on energy dynamics of lesser snow geese.

Wintering Pacific Black Brant in Mexico

Pacific black brant nest in colonies in western and northern Alaska and eastern Siberia. The entire population stages at Izembek Lagoon on the Alaska Peninsula from September through October on their way to wintering areas along the Pacific coasts of North America and Mexico. Mexico is used for wintering by more than 80% of the Pacific Flyway population. Because the wintering areas in Mexico are subject to increased industrial and commercial development and because the increased human activity may degrade habitats used by brant, the status of brant in Mexico has continent-wide implications.

Biologists from the Alaska Fish and Wildlife Research Center marked brant on their northern breeding colonies and, in a cooperative study with counterparts in Mexico, re-sighted 1,064 individuals 2,263 times in Mexico. Boats (65%) and hunting activity (23%) were the most important causes of the 242 disturbances recorded in the 130.5 h of daylight observations at San Quintin Bay, Mexico. Human-related disturbances accounted for 96% of all such events in the Bay. Further work will evaluate the effect of disturbance in other major Mexican wintering areas used by brant.

Wintering White-fronted Geese in California

By using a computer simulation model that compared energy expenditure to energy consumption, scientists at the Northern Prairie Wildlife Research Center determined an appropriate energy balance for greater white-fronted geese. Activities including feeding and flying were simulated with data from 3 years of field studies in the Klamath Basin in northern California.

Simulations where crops were removed from the Tule Lake National Wildlife Refuge resulted in significantly greater emigration and a decline in total goose use. Surprisingly, eliminating only the major crop, barley, did not reduce goose numbers but did increase foraging distance. Apparently, alternative foods such as potatoes can provide adequate nutrition. Eliminating hunting disturbance did not change goose use, but simulating a 10-fold increase in disturbance reduced goose numbers 30%. Food availability and disturbance did not seem to be factors critical to the recent decline of white-fronted geese in the Klamath Basin.

Predation on Nesting Pacific Black Brant

Nesting colonies of Pacific black brant on the Yukon–Kuskokwim Delta in Alaska have declined in abundance and size since the 1970's. In 1984 and 1985, arctic fox predation on nests at one of the largest remaining colonies resulted in almost complete reproductive failure. Alaska Fish and Wildlife Research Center biologists removed foxes by trapping and shooting at one colony from 1986 through 1989. A total of 52 foxes was removed with most (46) being removed during 2 years of relatively low tundra vole numbers (a major alternative food). Mean nest success in the brant colony was 82% during 4 years of fox removal. Mean nest success at another large colony where foxes were not removed during the same time was 54%, excluding 1 year in which only one fox occupied the area of the brant colony. Removal of arctic foxes to temporarily reduce local predation problems seemed successful in increasing nest success.

Canvasback Duckling Mortality in Minnesota

As part of an effort to identify the timing and causes of canvasback mortality throughout their life cycle, Northern Prairie Wildlife Research Center scientists studied canvasback ducklings from hatch to fledging at Agassiz National Wildlife Refuge in northwestern Minnesota during 1987–90. Previous studies had not identified mortality factors of young-of-the-year canvasbacks because either total broods were lost or the broods were scattered at an early age. Radio telemetry provided the technique to quantify duckling mortality and to determine whether skewed survival during the first year could be responsible for the skewed sex ratio favoring males in the population as a whole. Radio marked ducklings were located several times daily. Dead birds were recovered as quickly as possible, and post mortem examinations were made at the National Wildlife Health Research Center.

During the 4-year study, 226 radio-marked ducklings were placed in canvasback broods. Predation, exposure during cold and or wet weather, disease-related deaths, and starvation were the major causes of mortality. All ducklings were lost in 17 broods; only 4 of 52 broods fledged without loss of 1 or more ducklings. Female duckling survival to 25 days of age was significantly lower than that of males; no sex-related differences were found after 25 days. The causes of this differential survival have yet to be determined, but early differences in survival may be important in determining the sex ratio of the adult population.

Avian Mycoplasmas Affect Production of Young Waterfowl

Avian mycoplasmas are bacteria that are frequently isolated from domestic fowl and are known to decrease productivity and lower growth rates in young birds, as well as to cause respiratory disease and arthritis. Little is known concerning the occurrence and effects of mycoplasmas in wild waterfowl. Researchers at the National Wildlife Health Research Center, in collaboration with Northern Prairie Wildlife Research Center biologists, recovered *Mycoplasma anatis* and other mycoplasmas from breeding females, day-old ducklings, and carcasses of birds marked with radio transmitters during a 3-year study in Minnesota and North Dakota. A simulation of vertical (through the egg) transmission of mycoplasma was used to evaluate the pathogenicity of *M. anatis* by inoculating game-farm eggs. Pipping success of inoculated eggs was 10% below control eggs; hatching success (24 h post hatch) was 35% below control eggs. Further research is being conducted to assess the prevalence of *M. anatis* in duck populations, its effect on duckling growth, and its role as an additive to physiological stress.

Wood Duck Banding Analysis

Researchers at the South Carolina Cooperative Fish and Wildlife Research Unit demonstrated the feasibility of using early season banding data to refine annual survival and recovery rates of wood ducks in the southeastern United States. A large portion of the banding of wood ducks occurs during April–June when the birds are easily accessible in nest boxes, instead of the more standard July–September banding period. Continued analysis of banding data will produce recommendations on the most effective combination of early and traditional preseason banding quotas for wood ducks and improve our knowledge of the population dynamics of this reclusive species.

Effects of Harvest on Waterfowl Populations

Effects of harvest on waterfowl populations continue to be debated among researchers and managers. Until structured experiments can be conducted, biologists will continue to rely on correlation analyses of historical data for insights regarding the effects of hunting. Breeding populations, band recoveries, and harvest data from 1961 to 1985 were analyzed by biologists from the Migratory Bird Management Office and the Patuxent Wildlife Research Center to determine whether annual changes in the size of mallard breeding populations were related to measures of recruitment and survival. Changes in mallard breeding populations varied negatively with harvest rates and positively with production of young for the preceding years. The results support continued efforts to increase mallard breeding populations by controlling harvest rates and by directing habitat management efforts toward counteracting decreases in recruitment rates that were found in the last 20 years.

Waterfowl Band Recovery Data

Wildlife managers have been concerned that low reporting rates of waterfowl bands has decreased the effectiveness of banding programs and confounded interpretation of band recovery rates as indexes to hunting mortality. This prompted additional studies of band reporting rates. Dummy or nonfunctioning radio transmitters known to have reporting rates near 100% were used in the Mississippi Alluvial Valley during 1986–89 to estimate reporting rates of standard aluminum and $10 reward bands. Assuming that all transmitters were reported, Patuxent Wildlife Research Center biologists found that reporting rates were 16% for standard bands and 35% for $10 reward bands. The results indicated that reporting rates for standard bands in the Mississippi Alluvial Valley, a major harvest area, are less than the average (32%) for most of North America.

Habitats of Concern in the West

Two areas in California are of particular concern to waterfowl biologists. The first, San Francisco Bay area, has great problems associated with human population density that pose a substantial threat to the remaining wetland resources. Biologists from Northern Prairie Wildlife Research Center conducted semimonthly aerial waterfowl surveys on the open bays and salt evaporation ponds of San Francisco Bay between October and April, 1989–90. Peak counts of more than 284,000 waterfowl were recorded during winter, including lesser and greater scaup (45%), surf scoter (20%), northern shoveler (13%), ruddy ducks (7%), and canvasback (7%). Salt evaporation ponds comprise only 23% of the areas but contained 34% of the waterfowl. The majority (94%) of the waterfowl were found on ponds where salinity was less than 94%. Diving ducks dominated the open bay regions, but 62% of the waterfowl were seen in areas where the water depth was less than 5 m.

A second area of concern was the Tulare Basin. Less than 5% of the original wetlands acreage of the San Joaquin Valley remained. Evaporation ponds made up about 40% of the remaining wetland acreage for wintering waterfowl. Northern Prairie Wildlife Research Center scientists evaluated habitat use patterns of wintering waterfowl by analyzing aerial surveys of wetland and waterfowl abundance from 1980 through 1987. Density of total ducks was greatest in September because early arriving migrants accumulated on preirrigated agricultural lands in the Tulare Basin. Northern pintails made up more than 86% of the total on these areas. From October through January, total duck densities (mostly teal) were greater on Kern National Wildlife Refuge than on other wetland types. Kern Refuge and preirrigated fields had comparable densities, but the highest densities of three of the five most common species were found on the refuge.

Other Migrant Birds

Biologists at the National Ecology Research Center are continuing studies to describe strategies of mid-continent movement used by shorebirds that migrate internationally. The unique nature of different geographic regions within the interior United States is highlighted by the variable patterns of species composition and abundance between regions. Smaller species and neotropical migrants move primarily across the Great Plains. The larger species and North American migrants predominate where shorebirds assemble in the Intermountain West. Throughout the interior, shorebirds are widely dispersed over wetland landscapes with dynamic water regimes. In contrast to coastal migrants that concentrate at sites of seasonally predictable and abundant food resources, transcontinental migrants seem to use wetlands both opportunistically and less predictably.

Western Neotropical Migrant—Willow Flycatcher

Recently detected yet widespread population declines have led to growing concerns about to the long-term conservation of neotropical migratory birds. Forest fragmentation on the breeding grounds and deforestation of wintering habitats are the primary factors responsible for the population declines. Whether the problems are primarily on the breeding grounds or on the wintering grounds remains unclear, but neotropical migrants may be responding to the cumulative effects of patterns of land use management in both areas.

Biologists at the National Ecology Research Center have begun long-term studies on the population dynamics, reproductive success, and habitat relations of willow flycatchers at Malheur National Wildlife Refuge to help answer these questions. This species, which in the western United States is composed of a mosaic of healthy and threatened populations, has been selected as a model species for detailed ecological study. While the population at Malheur seems healthy, large annual and local differences in population densities, parasitism by brown-headed cowbirds, and reproductive success suggest a complex pattern of recruitment.

Preliminary results indicate a high degree of site tenacity for adults and a lower, but delayed, tenacity for juveniles, emphasizing the importance of habitat continuity. Parasitism by brown-headed cowbirds, highly variable across both localities and years, may severely limit recruitment—both directly by preempting successful fledging and indirectly by reducing survival of late-fledging nestlings.

Nearctic Migrant Birds

Many of the migratory bird species that breed in North America are experiencing population declines. The causes are undoubtedly multiple. Some operate in breeding, migration, and wintering areas and all vary in importance with each species. On breeding grounds, habitat fragmentation, nest predation, and cowbird parasitism are probably the factors most important in population declines. Loss or degradation of habitat is of greatest significance during migration and on the wintering grounds.

Of the about 650 species that breed in the United States, 332 (or more than 50%) spend from 3 to 6 months each year in migration or on wintering grounds in countries to the south. The avifauna of each country of Central and South America and the Caribbean includes some wintering nearctic migrants, and some migratory species probably winter in every major habitat type in Latin America.

All natural habitats in Latin America are being degraded or destroyed at unprecedented rates. Current projections suggest that by the turn of the century only remnants of tropical forests will remain in many countries, and forests in others will be severely reduced. Other types of habitat, especially grassland and wetland, are equally threatened.

Regardless of all conservation efforts, much or most of the habitat occupied by migrating and wintering species from North America will be developed to some degree. It is critical that we develop means of enhancing or restoring disturbed habitats to maximize their suitability for organisms displaced from their natural areas.

Habitats can be enhanced by increasing food availability or mimicking habitat conditions. Biologists from the Biological Survey of the National Ecology Research Center are working with counterparts in southern Mexico to identify the species of fruits used by forest-dwelling wintering migrants. Although most North American migrants are largely insectivorous during the breeding season, many eat large quantities of fruit during the winter or before spring migration. Once the important plants are identified, their suitability for use as ornamentals or shade trees around dwellings, as living fence posts, or for windrows between fields can be determined. Such habitat islands in areas of extensive cultivation can substantially increase habitat use by birds.

Bristle-thighed Curlew Status and Demography

The bristle-thighed curlew is the only species of curlew whose status is largely unknown. Bristle-thighed curlews winter in the island groups of the central and south Pacific Ocean and breed on the Seward Peninsula of Alaska. In 1988, scientists at the Alaska Fish and Wildlife Research Center started a major effort to determine the status of the species. The field investigations focused on life history parameters on the breeding, staging, and wintering grounds. A comprehensive management plan will be developed.

Recent studies suggested that fewer than 10,000 individuals remain. Potential threats to the population include subsistence hunting on the wintering grounds, exposure to contaminants, and predation from introduced mammals.

Preliminary analysis of data provided an estimate of about 3,250 pairs. In 1991, 36 pairs were located on the Seward Peninsula study site and about 78% successfully fledged young. Seventeen of 22 birds (77%) marked during 1990 returned to the study area in 1991. An additional 36 adults and 25 juveniles were captured and color-banded in 1991.

Cooperative efforts with Montana Cooperative Wildlife Research Unit researchers on the wintering grounds in the northwestern Hawaiian islands documented flightless molt and extreme longevity (>20 years) among adults and confirmed differential timing of migration among age classes. Only a small portion of the breeding population (about 350 birds) stopped on Laysan Island during southward migration.

Seventh Straight Breeding Failure Recorded for Black-legged Kittiwakes on Middleton Island

Seabird populations number more than 100 million individuals of about 50 species. Another 20 million or more seabirds from the Southern Hemisphere forage in Alaska waters during summer. Recreational and commercial fisheries, offshore oil and gas development, and oil spills pose threats to these marine bird populations in Alaska.

Researchers from the Alaska Fish and Wildlife Research Center studied seabirds on Middleton Island in the Gulf of Alaska. Middleton Island was selected because productivity estimates suggested that the site was representative of sites in the Gulf of Alaska. The main goal was to determine adult survival and energetics of black-legged kittiwakes. More than 80 estimates of annual productivity were available since 1976 for kittiwake colonies in Alaska. Little or no new recruitment of breeding adults was found in many of the largest colonies. Adults died in large numbers during the summer months in some years, and population declines were observed. Reasons for the declines remain unknown.

Adult mortality during the winter of 1989–90 was estimated by resighting birds banded on Middleton from 1984 to 1988. Over 100 new adult kittiwakes were captured and banded in 1990. Adult over-winter survival was estimated at 93–94% over the last 3 years, far exceeding the values known for Atlantic populations of this species. The high survival rates could not offset the chronic reproductive failures. The seventh straight year of total or near-total breeding failure on Middleton occurred in 1991. Failure seemed related to an inadequate food supply, although predation by a rapidly expanding gull population was the major proximate cause of egg and clutch losses in the colony.

Puffins May Provide a Useful Index of Pollock Distribution and Abundance

Commercial fishing in Alaska's coastal zone has increased dramatically in recent years. Seabird populations often suffer when fish stocks used for food are overfished, and competition with seabird populations may cause conflict between the commercial fishermen and seabirds. Data are lacking to determine if depleted fisheries stocks adversely affect Alaska seabirds, but data are available to show adverse effects elsewhere.

Food habit studies of tufted and horned puffins were investigated in 1982. Biologists at the Alaska Fish and Wildlife Research Center sampled the nestling diets of tufted and horned puffins for 3 years in colonies from the north-central Gulf of Alaska to the eastern Aleutian Islands. Overall, tufted puffins consumed (by weight): sandlance, 41%; capelin, 22%; walleye pollock, 19%; other fish, 8%; and invertebrates, less than 1%. Horned puffins consumed: sandlance, 85%; capelin, 4%; pollock, 2%;, other fish, 8%; and invertebrates, less than 1%.

All pollocks consumed were young-of-the-year, whereas four year classes of capelins were present, from young-of-the-year through spawning adults. Puffins took mostly first-year sandlance, but fish in their second year or older were common prey at colonies near Kodiak, Alaska.

An estimated 11 billion pollocks were consumed by tufted puffins throughout the region in 1986. The proportion of pollocks in puffin diets at the Semidi Islands was strongly correlated with independent estimates of cohort strength. Evaluation of food habits may provide a useful index of distribution and year-class abundance of first-year pollock, a species that currently supports an important commercial fishery in the Gulf of Alaska.

Ecology of Post-fledging American Kestrels

Biologists at the Iowa Cooperative Fish and Wildlife Research Unit, in cooperation with the Iowa Department of Natural Resources, the Iowa Department of Transportation and several other sponsoring groups, completed a 3-year study of the behavior and ecology of American kestrels after fledging. Most of the kestrels fledged from nest boxes attached to the backs of highway signs along Interstate Highway 35; a few fledged from nest boxes off the interstate. To monitor kestrel activity, radio-transmitters were attached to nestlings just before nest departure. The project objectives were to determine the behavior, use of habitat and perches, causes of mortality, and the time until dispersal of post-fledging kestrels.

During the first week after nest departure, kestrels spent <1% of their time hunting or flying; the remainder was spent in inactive behavior. Kestrels that fledged from nests along the interstate were seen primarily in cropland and along the interstate right-of-way, where they were seen frequently on the ground.

All but 1 of the 16 kestrels found dead died during the first week after fledging, before flying skills had developed. Mammalian predation accounted for six deaths and was the main cause of mortality. Only 2 of 61 radio-marked kestrels that fledged from nest boxes along the interstate died because of a collision with a vehicle.

As kestrels grew older, resting on perches decreased and hunting from perches increased. Post-fledging kestrels fed almost exclusively on invertebrates. Mean hunting success did not exceed 55%. Social hunting seen among siblings, families, and unrelated kestrels, occurred from both ground and perch and was imitative rather than cooperative.

Kestrels that fledged from nest boxes along the interstate hunted extensively along secondary roads. Mean number of days from fledging to dispersal was 22.7. Band recoveries provided little evidence of kestrels returning to natal nest boxes.

Population Dynamics, Foraging Ecology, and Management of Gulls on Momomoy National Wildlife Refuge

Herring and great black-backed gull populations on Monomoy National Wildlife Refuge increased from 5 pairs in 1963 to an estimated 19,500 pairs in 1984. Concurrent with the rapid growth in numbers of nesting gulls was a decline in numbers of other beach-nesting birds, including common, arctic, and roseate terns, and the piping plovers. Although changes in gull and beach-nesting bird populations were documented, little was known about the factors responsible. The reason(s) for the gull colonies' growth, resources that support the colonies, and relations between gulls and beach-nesting birds had not been identified. Scientists with the Massachusetts Cooperative Fish and Wildlife Research Unit obtained biological and ecological data useful for the management of gulls on Monomoy National Wildlife Refuge.

Although adult herring and great black-backed gulls both consumed refuse during the breeding season, great black-backed gulls were less dependent on refuse and more dependent on natural foods than were herring gulls. Therefore, conversion of Cape Cod landfills to transfer stations, one proposed solution, will have a greater effect on Monomoy's herring gull numbers than on great black-backed gull numbers.

Simulation modeling indicated that none of the strategies now used or proposed for use on Monomoy (i.e., control, egg destruction, egg oiling, DRC-1339, and DRC-1339 followed by egg oiling) would eliminate Monomoy's nesting gull populations within a 10-year management period. Significant reductions in the gull populations would require long-term commitment of personnel and funds, but the effort would not assure an increase in the refuge's tern populations. The continued presence of great horned and short-eared owls and black-crowned night-herons as predators near Monomoy's tern colonies suggested that intensive management would be required to increase tern nesting success.

Habitat Use by Migrant Shorebirds and Invertebrate Availability in a Managed Wetland Complex

During 1988 and 1989 the National Ecology Research Center commissioned a group of University of Missouri researchers to document the migration chronology and habitat use of shorebirds at Cheyenne Bottoms Wildlife Management Area in Kansas. Objectives were to determine if relations exist between invertebrate availability and shorebird use, and to develop a model to estimate the amount of foraging time required for shorebirds to gain 1 g of body mass per day. Thirty-four species of shorebirds were seen during the study. Shorebirds were present at Cheyenne Bottoms from mid-March through late October, although peak migrations occurred between early April to mid-May and mid-July to mid-September.

During spring and summer to fall, timing of migration differed among similar-sized species of the same foraging guild. Foraging habitat use differed among species of similar size, and foraging mode differed based on water depth. Shorebird abundance was related to chironomid biomass; foraging time required to gain body mass was influenced by size of chironomids available. Between 1988 and 1989, foraging hours per day required to add 1 g of body mass were reduced because of a change in the size structure of the available chironomids.

New drawdown and flooding strategies were recommended to develop a food base and provide continuous availability of invertebrates for shorebirds. Wetland managers will identify habitat requirements for shorebirds and manipulate water levels within wetland complexes to optimize the availability of invertebrates.

Bird Use of Conservation Reserve Program Lands in the Prairie Pothole Region

The Conservation Reserve Program (CRP) established in 1985, allowed conversion of large areas of marginal cropland in the prairie pothole region to permanent cover. Northern Prairie Wildlife Research Center scientists initiated a study to determine the use by breeding birds of CRP fields in western Minnesota, North and South Dakota, and eastern Montana.

Nine counties were selected based on physiographic landform and the extent of CRP fields. Individual fields were chosen based on location, on size, on CRP practice employed, and permission from landowner. During late May to early July, 1990 and 1991, birds were censused on 240–320 CRP fields ranging in size from 0.5 to 73 ha (1.2 to 180 acres).

The most common birds on CRP fields were lark bunting and grasshopper sparrows, followed by red-winged blackbirds, horned larks, western meadowlarks, and savannah sparrows. In contrast, limited information on croplands in the prairie pothole region showed horned larks most abundant, followed by chestnut-collared longspurs, and lark buntings.

Breeding Bird Survey data indicated population declines in recent years for several grassland species, including grasshopper sparrows, lark buntings, bobolinks, clay-colored sparrows, Baird's sparrows, and dickcissels. Because these species are more common in CRP than in cropland, the Conservation Reserve Program has potential to reverse the downward population trends of these species.

Upland Sandpipers Affected by Grazing

Populations of many grassland birds have declined during the past 100 years because of loss of native prairies. Persistence of sensitive grassland species depends on their ability to breed successfully in habitats influenced by human activities. The upland sandpiper, a medium-sized shorebird, is a Neotropical migrant that breeds in grasslands of North America and winters in the pampas of southern South America.

Researchers at Northern Prairie Wildlife Research Center conducted a 7-year experimental study to examine the effects of grazing on nest density and nest success of upland sandpipers. The grazing treatments studied were ones likely to be used by managers of national wildlife refuges and other public lands where the objective of grazing is to manage the grassland to enhance prairie and wildlife.

Nest density was lower for treatments where cattle were present than where cattle were not present during the nesting season. Grazing treatment did not influence nest success. Researchers recommended that public lands with breeding populations of upland sandpipers should include a complex of fields under various management practices, including fields undisturbed by grazing during the nesting season.

Population Dynamics and Habitat Use of Roseate Terns

In 1987, scientists at Patuxent Wildlife Research Center began a cooperative study of the population dynamics and habitat use of roseate terns at the four largest colony sites in the region from Long Island, New York, northeast to Buzzards Bay, Massachusetts. The major objectives were to determine population trends, estimate survival and intercolony movement rates of adults, determine annual productivity, and experiment with nesting habitat management techniques to increase breeding success. The breeding population of roseate terns at the four study sites remained roughly stable at about 3,050 pairs, but an analysis of the capture and resighting data on more than 1,700 color-banded adults resulted in an estimated annual survival rate of 0.80.

The two largest colonies consistently produced more than one chick per pair each year. Only 16% of all fledglings from the third largest colony site at Falkner Island, Connecticut, survived to maturity, and about 66% of the known recruits at this site were immigrants from other sites. The relative high rate of production at two colonies, the stability of those colonies, and the stability of the two colonies with low production, indicate that the two largest colonies are responsible for stability of the entire northeastern regional population.

Modification of the nesting habitat increased production at Falkner Island. In 1989, for example, 51 pairs that used naturally occurring rocky sites produced only 0.55 fledglings per nesting attempt, while 26 pairs that used boxes produced 1.04 fledglings, and 55 pairs that used tires half-buried in gravelly areas produced 1.16 fledglings per nesting attempt. Use of similar habitat enhancement techniques elsewhere may allow establishment of new breeding sites and help the recovery of the northeastern breeding population.

Population Trends of Neotropical Migrants

Indications of population declines in neotropical migrant songbirds have caused increased research into both methods of detecting and causes of population changes in birds. Biologists at Patuxent Wildlife Research Center have examined geographic patterns in population changes in neotropical migrant birds using data from the North American Breeding Bird Survey. Distinct regional and temporal patterns exist in population changes among these species. Over the long-term (1966–88), no evidence exists that a disproportionate number of neotropical migrant species are declining. Examination of a shorter interval (1978–88) indicates that a majority of species has declined in recent years. During both intervals, extensive regional variation existed in patterns of population change, with species generally exhibiting increasing populations in the western part of the continent. The temporal and geographic patterns of population change in neotropical migrants suggested that caution is necessary in making general statements about the declines in neotropical migrant birds. Recent declines in eastern neotropical migrants that breed in forested habitats are a cause for concern among conservationists. Biologists at Patuxent are studying many aspects of neotropical migrant survival, reproduction, and population change in breeding, migration, and wintering areas.

Forest Fragmentation and Neotropical Migrants

The Breeding Bird Survey annually samples bird populations at 100,000 points along 2,000 randomly distributed roadside transects throughout the continental United States and southern Canada. Since 1966, this survey has documented declining populations in many species of marshland, field, and forest birds. Among forest birds, those most consistently declining are neotropical migrants. Total populations of breeding birds have declined in study plots sampled over 30 to 40 years, but some of the short-distance migrants have increased while the neotropical migrants have declined. Factors contributing to the reduction in neotropical migrants include landscape changes on the breeding grounds, increase in migration casualties, and loss of tropical forest. Scientists at Patuxent Wildlife Research Center found that the decline was most severe among species that require forest habitats in both summer and winter, and was most noticeable in areas with high rates of forest loss and fragmentation. Center scientists have found that on the tropical wintering grounds in the West Indies, Mexico, and Central and South America, many forest migrant species also use fragmented, suburban, and disturbed habitats, and even some of the agricultural habitats. Migrants that feed on the forest floor, including thrushes and some wood warblers, require tropical forest habitat. Resident tropical species are especially sensitive to forest fragmentation, and avoid the forest fragments as well as the agricultural habitats. Thus, conservation of tropical forests should be of special concern not only to the United States and Canada, but also to Caribbean and Latin American countries.

Riparian Corridors and Neotropical Migrants

In agricultural landscapes, much of the remaining forest is in linear tracts along streams. These riparian forests vary in width. Very narrow corridors may only provide forest-edge habitat and may not provide sufficient forest interiors for many forest birds. Researchers at Patuxent Wildlife Research Center investigated the relations between the width of the riparian forest and the presence of bird species in the center of the corridor. The number of neotropical migrant species was significantly related to corridor width, and several species that are considered sensitive to forest fragmentation were less likely to be found in corridors <100 m wide.

Point Counts: Roadside versus Off-road

Many species of birds are monitored from roadside surveys because roads provide an efficient way to survey a large area. However, the question remains whether roadside counts obtain a representative sample of species that would be found in similar habitat away from the road. Biologists at Patuxent Wildlife Research Center conducted an experiment that compared the results of point counts conducted along roads to counts conducted 200 m and 400 m away from the road in similar forest habitat. Results from 81 paired road and off-road counts in the Shenandoah National Park indicated that roadside counts detected all species found off-road as well as more species and more individuals than off-road counts. Thus, while more edge species were detected from roadside counts, no forest species were missed by roadside counts.

Upland Game Birds

Effects of Prescribed Burning on Wild Turkey Habitat Selection

Biologists at the Alabama Cooperative Fish and Wildlife Research Unit, in cooperation with Tall Timbers Research Station examined wild turkey habitat selection on a southern Georgia area with a long history of prescribed burning. This radio-telemetry project was conducted from 1988 through 1990.

Pine uplands left unburned for 1–3 years were avoided for general travel but were highly preferred for nesting. Annually burned pinelands were used more post-burn than preburn. Green ups stimulated by burning from December to February were avoided by turkeys during winter. Pine–hardwoods, hardwoods, and fields of waste corn or cool-season grasses were used. Forest openings were preferred in

Wild turkeys in Georgia preferred a mosaic of habitats that varied seasonally. The birds used land belonging to several landowners. Cooperation among landowners is desirable to maximize flock management according to researchers at the Alabama Cooperative Fish and Wildlife Research Unit.

spring of both years. Old-field pine plantations were preferred the first spring after planting but were avoided the second spring.

Hens with young broods preferred old fields and woodlands grazed by cattle. Insect abundance in intensively used brood areas was significantly greater than in typical winter burned pinelands where no brood use was detected.

Average home range size for gobblers was 842 ha (2,080 acres) on this area of primarily annually burned pinelands. Gobbler combined ranges encompassed nine different properties averaging 760 ha (1,878 acres). Mortality of young poults and insufficient brood habitat were found to be severely limiting the turkey population. A cooperative effort in turkey management among several adjacent land holdings seems to be the only way to obtain the full potential of the habitat.

Wild Turkeys and Agriculture in Northeastern Iowa

In the highly agricultural State of Iowa, flourishing wild turkey populations resulting from a successful reintroduction program have been the subject of increasing numbers of informal landowner/operator complaints about damage to spring and fall crops. State wildlife agencies, on behalf of turkey hunters and others, wish to maintain high density turkey populations on these private lands. Wildlife managers find themselves in a challenging situation, managing a highly sought after game bird as a public resource on private lands where its presence is sometimes considered damaging to agricultural crops.

Because publicity and attention created by real or perceived turkey damage could influence land management decisions, a study sponsored by the National Wild Turkey Federation was undertaken by the Iowa Cooperative Fish and Wildlife Research Unit. The objectives were to determine landowner or operator perceptions of turkey damage, and the extent of turkey use of corn and oats in a mixed forest–agriculture ecosystem. A preliminary survey of 337 Iowa landowners or operators found that 64% of those with wild turkeys on their land felt they had suffered some loss. Mature corn was the crop most often reported damaged.

Because of high turkey density and visibility, presence of turkeys in agricultural fields seemed a threat to crops. The study results suggest that turkey damage may be overestimated. Spring damage ascribed to turkeys was found more likely to be caused by less visible wildlife including ground and tree squirrels or deer. Actual loss of corn in the field because of turkeys was estimated to be less than 1%.

Evaluation of a Habitat Suitability Index Model for Ring-necked Pheasants

Biologists at the Iowa Cooperative Fish and Wildlife Research Unit, in cooperation with the National Ecology Research Center, evaluated a Habitat Suitability Index (HSI) model for the ring-necked pheasant. The biologists compared pheasant numbers to habitat changes in central Iowa between 1981 and 1990. Pheasant numbers were recorded on 5-mile segments of Iowa Department of Natural Resources roadside count routes. Remote sensing and land classification using a GIS were performed to calculate HSI values. The data were divided into two groups: years where no on-ground habitat maps were available during habitat classification activities (1981, 1984, and 1988), and years where complete habitat information was available (1989–90).

More than 331,000 ha were included in the GIS analysis. Pheasant numbers were negatively related to alfalfa and hay acreage and positively related to pasture lands. Regression analysis of data without on-ground habitat maps revealed that no habitat variables were significantly related to pheasant observations. A multiple regression model for the 1989–90 data contained four habitat variables and was highly significant. Three habitat variables contained in the model (disked corn stubble, soybean stubble, and oat stubble) were crop and fall field treatment variables and were positively related to pheasant numbers, suggesting row crop acreage plays an important role in pheasant ecology. The other variable, alfalfa or hay, also had a positive relation to pheasant numbers in the 1989–90 data.

Detection Rates Using Drive Count Survey of Radio-marked Northern Bobwhite

Scientists with the Missouri Cooperative Fish and Wildlife Research Unit radio-marked northern bobwhites to determine detection rates during drive count surveys and to follow bobwhite movements during the hunting season. Fifteen drive counts were conducted on a 259-ha study area. Each drive count required an average of 14.4 person-days to complete. Counters walked 10 m apart across the area until the entire area had been transversed. Investigators with radio receivers walked behind the counters and monitored radio-marked bobwhites to determine if they were flushed or missed by the counters.

Detection rates of individual birds and coveys were 56% and 61%, respectively. No differences in detection rates were found between years or habitats. Small game hunting pressure on the study site was 877 and 488 gun hours per 100 ha, respectively, for the 1987 and 1988 field seasons. The birds responded by making daily movements related to hunting pressure. The total number of bobwhites flushed by hunters was also related to daily movements by bobwhites. Although the relations were significant, results indicated that factors other than hunting pressure might be more important in influencing bobwhite movements.

Population Trends of Woodcock

The secretive, nocturnal American woodcock can be surveyed effectively only in spring when its breeding display is audible (and sometimes visible) during early evening. Wildlife biologists at the Patuxent Wildlife Research Center, in collaboration with biologists at the Office of Migratory Bird Management, examined the population changes in woodcocks over the 19 years of the Singing-ground Survey. The survey, which is coordinated by the Fish and Wildlife Service and the Canadian Wildlife Service, provides the only systematically collected information on woodcock populations throughout most of their breeding range. Woodcock populations have consistently declined in most of the eastern United States and eastern Canada over the survey interval. In the central part of the continent, populations were stable through most of the 1970's. Woodcock declined in the central States and provinces during the 1980's. Unfortunately, survey data allow documentation of population changes but provide only limited information about cause. Studies by Patuxent biologists have implicated large-scale habitat changes on both breeding and wintering ranges as a major factor associated with woodcock population declines.

Owls

Diet and Habitat Selection of Nesting Common Barn-Owls in Ohio

Habitat and land use were analyzed by researchers at the Ohio Cooperative Fish and Wildlife Research Unit within 2 km of 53 barn-owl nest sites (mostly nesting boxes) and three roost sites active during 1978–89. Habitat within 1 km of nest sites had significantly less woodland, but not significantly more grassland, than habitat 1–2 km from the nest. Ohio's endangered barn-owls selected nest sites without large woodlots nearby, apparently to avoid a significant predator, great horned owls. Boxes used once for nesting had 271.6 ha of grassland within 2 km of the box, whereas boxes used more than once had 333.6 ha within 2 km. This is three-fold increase over the amount of grassland that has been used as a guideline by other States. Of 4,744 vertebrate prey items identified in barn-owl-pellets, 71% were of rodents in the subfamily Arvicolinae; most were meadow voles.

Wetlands

Wetlands as Habitats

Riverine and Riparian Habitat Assessment Methods

Scientists at the National Ecology Research Center have developed an assessment method for riparian vegetation. The procedure uses hydraulic models of the Instream Flow Incremental Methodology and extends consideration of the potential effects of water management from instream habitat to riparian vegetation and associated habitat values. The procedure is based on an environmental gradient of vegetation as related to hydroperiod, or fraction of time inundated. A flow exceedance representation of the historical flow regime is used to determine inundation period at points in the riparian zone. This calibrated direct gradient model can then be used to predict the vegetation associated with alternative flow regimes by substituting alternative flow exceedance curves.

The model has been used to analyze existing riparian vegetation on several western rivers and has recently been used in a water management assessment on the Gunnison River in Colorado. The primary advantages of the model are its powerful use of standard hydraulic models and hydrologic data, and its relatively simple vegetation sampling requirements. Refinements of this model are being made to integrate channel change with vegetation dynamics and to provide more detail on individual species and short-term fluctuations in vegetation composition.

A critical problem in the Middle Rio Grande River in New Mexico is lack of cottonwood regeneration. Analysis of the forest age structure showed that some of the poor regeneration could be explained by modification in the hydrologic regime. The regeneration problem was exacerbated by channel maintenance and stabilization activities that have restricted the channel to a relatively narrow active band. Mesocosum studies have demonstrated that plains cottonwoods required a several-day period with substrate saturation for seed germination. Survival and growth of seedlings required full sun and groundwater declines ≤ 0.4 cm per day. Water management practices could facilitate natural regeneration of plains cottonwood, but substantive changes in flow regimes may be required and may conflict with other uses.

Scientists at the National Wetlands Research Center continue to test and improve FORFLO, a succession model for bottomland forests that simulates the growth and development of individual trees and species as influenced by floodplain hydrology. The scientists evaluated a backcasting technique that would allow the model to predict past forest conditions.

Backcasting is a new technique of modeling the growth dynamics of forest stands backward through time. It involves loading a forest simulator with actual stand data and predicting the growth and competitive dynamics that led to current stand development. Data input to the model includes stem-mapped and tree-cored individuals from oak-bald cypress stands in the Ouachita River bottomlands of the Felsenthal National Wildlife Refuge. The study demonstrated that backcasting is a robust technique to test model results. Research in progress includes modifications to the FORFLO model to test the effect of alternate gap sizes and canopy classes on model performance and accuracy. Statistical analyses are determining the growth relation of oak species to the climate and hydrology of the study site. These findings are improving the environmental functions presently used in the FORFLO model.

The reliability of another habitat estimate impact model–the Instream Flow Incremental Methodology (IFIM)–is strongly linked to habitat suitability criteria (HSC) that delineate the quality of microhabitat conditions for aquatic species or life stages. The lack of a reliable testing procedure has hindered the ability of IFIM users to evaluate the transferability of the HSC from source study streams to destination or application streams.

Scientists at the National Ecology Research Center have developed testing procedures that may eliminate this problem. The first element is to select criteria from a source stream that contains a variety of microhabitat conditions from which the target organisms can select. The second element is the sampling design. Rather than sampling different habitat types in the proportion that they are found in the stream, equal areas of all habitat types are sampled an equal number of times. This results in a moderate adjustment of the HSC compared to traditional mathematical corrections. The equal-effort sampling approach requires less field data than the mathematical correction, and data produced by this method are easily pooled for different reaches or different streamflows.

The testing procedure involves the measurement of both occupied and unoccupied locations in the destination stream. Candidate HSC are used to calculate the relative suitabilities (e.g., optimal, marginal, or unsuitable) in test stream habitat locations. A one-sided, chi-square test is then used to test for non-random selection of optimal over marginal locations and suitable locations (optimal and marginal, combined) over those calculated to be unsuitable. To be considered transferable, a set of HSC must pass both tests.

The reliability and robustness of the test procedure have been extensively evaluated in several Colorado rivers using HSC obtained from the South Platte River in central Colorado for active adult and juvenile rainbow trout. The HSC from the South Platte were found to be transferable to adult rainbow trout in the Cache la Poudre in northern Colorado. HSC developed for juvenile rainbow trout in the South Platte were not transferable to adults. Literature based HSC obtained from the Fish and Wildlife Service Blue Book were likewise found to be non-transferable to the Cache la Poudre River.

The HSC developed in the South Platte River for rainbow trout and brown trout were transferable to the Rio Grande River in southern Colorado. These results support the concepts of source stream diversity and equal-effort sampling as means of testing the transferability of HSC. These HSC will be tested in other geographic regions in the future and similar transferability testing of HSC will be carried out for smallmouth bass and rock bass habitats throughout north central and northeastern United States. The ultimate goal of this testing campaign is to assist IFIM users in correctly matching HSC to the characteristics of the destination stream.

Productivity of Riparian Wetlands

Biologists at the Iowa Cooperative Fish and Wildlife Research Unit recently completed a study along the Platte River in Nebraska to examine the role of wet meadow macroinvertebrates in the feeding ecology of sandhill cranes. Macroinvertebrates constituted 89% of the crane diet in wet meadows, while plants constituted 11%. Scarab beetle larvae accounted for 68% of the diet, while earthworms and other invertebrates comprised the rest. Because wet meadows are extensively used by cranes, management should be focused on maintaining abundant populations of earthworms and scarab beetles in the upper soil strata in spring. This can be accomplished by maintaining moderate water table depths (40–80 cm) below these lowland habitats.

Western Pond Turtle in Southern California

The western pond turtle associated with riparian habitats in southern California is being considered for listing as threatened by the Fish and Wildlife Service. To better understand the reasons for the decline and to be in a better position to achieve recovery in the event of listing, National Ecology Research Center scientists initiated research on nesting habitats of the turtle. Radio-tracking demonstrated that during the summer, gravid females were leaving the creek beds in late afternoon and traveling into adjacent upland grasslands up to 70 m from, and 11 m above stream courses. Protection of a wide corridor of undisturbed riparian habitat may be essential to ensure successful reproduction.

Delineation as an Issue

Scientists of the National Ecology Research Center scientists, in cooperation with the Iowa Cooperative Fish and Wildlife Research Unit personnel, studied relations among vegetation, soil and hydrology in wetlands in the Nebraska Sandhills from 1988 to 1991.

By 1986, wetland losses were estimated in excess of 30% for the entire Sandhills region. The region remained critical as nesting and migration sites for millions of waterfowl, songbirds, and shorebirds, as well as habitats for fish and terrestrial wildlife. Delineation as wetlands is critical for their protection and management. The study examined use of the unified Federal method in delineating wetland boundaries in the Crescent Lake National Wildlife Refuge area and compared direct and indirect measures of wetland hydrology. Researchers found that a large portion of the Sandhills consisted of a hydric soil type difficult to recognize by indirect measures because of its lack of typical hydric characteristics. These soils may have been wrongly classified as upland soils and need to be reclassified. Both vegetation and soils data were related to the direct (depth to water table) and indirect (soil moisture content) measure of hydrology. Vegetatation and hydrology were related more closely than soil and hydrology. Soil series could be distinguished by depth to water table but not by soil moisture content. Finally, in the unified Federal method, a wetland must have less than 45.7 cm (18.0 in) to water table. For Sandhill wetlands, depths less that 75.0 cm (29.5 in) were found to be more realistic.

Of the three designation criteria (plants, soils, and hydrology), wetland hydrology is most difficult to document because of annual, seasonal, or daily fluctuations. A more sensitive index of hydrology for delineating boundaries of Sandhill wetlands is critical.

Wetland Restoration and Management

Success in creating, restoring, managing, or enhancing wetlands requires knowledge of the functions and values of natural wetland complexes. Unless restoration guidelines are based on an understanding of natural systems, the process becomes one of trial and error. An interdisciplinary study by scientists from the Northern Prairie Wildlife Research Center and U.S. Geological Survey examined the role of the hydrology in prairie pothole wetlands. These wetland communities are controlled by: (1) annual fluctuations in water level and dissolved salts that establish and maintain vegetative zones; (2) long-term trends in climatic conditions cycling semipermanent wetlands between extremes of flooding and drawdown; and (3) locations of wetland basins with respect to groundwater gradients that control salt concentrations.

Wetland basins high in elevation are dominated by calcium bicarbonate water, have plant communities indicative of water with low salt content, serve as ground water recharge areas, and flood seasonally. During extended dry periods, shallow marsh zones of seasonally flooded basins at high elevations are invaded by terrestrial plants.

Wetlands lower in elevation function as groundwater discharge and recharge areas, are dominated by calcium and magnesium sulfates and bicarbonates, and have plant communities indicative of water higher in salt content than wetlands of higher elevation. Extended periods

Western pond turtle nesting habitats have been located by radio tracking. Nest sites up to 70 m from stream courses indicate that a wide corridor of riparian habitat may need protection.

of drought also increase the salt content of the water, and salt-tolerant species germinate. As water tables drop in response to extended drought, flow-through systems function as recharge areas, salt concentrations are reduced, and cattails germinate. Evaporation causes dissolved salts, dominated by sodium sulfate, to accumulate, and plant species tolerant of high salt concentrations become dominant. Exposed salt crystals are removed by wind action and deposited in the upland.

Semipermanent wetlands cycle between extremes in water level from highs that eliminate emergent vegetation to drawdowns that expose mud flats, allowing reestablishment of emergent vegetation. Cattail monotypes form once the central zone of a wetland basin becomes dominated by cattails. These wetlands did not revert to the open water conditions that prevailed during the early years (1967–72) of the investigation. Management practices that control flooding, drawdown, and salt concentrations have the potential to manipulate cattail monotypes.

Marsh Management

More than half of the Atlantic coastal marshes from Maine to Florida have been filled, degraded, or altered for mosquito control over the past 50 years. Many county authorities have implemented Open Marsh Water Management (OMWM) that employs biological control. A system of small shallow ponds and connecting radial ditches enables small fish to persist in marsh areas and to consume mosquito larvae. Biologists at Patuxent Wildlife Research Center studied the response of migratory birds to these alterations on several national wildlife refuges from 1987 to 1991.

Aerial surveys comparing OMWM ponds with nearby ponds indicated that waterfowl, shorebirds, waders, gulls, and other species had no overall preference for pond type. Waterfowl numbers were correlated with a high water-to-marsh ratio. Observational data indicated that all bird species used large ponds more than small ponds. Shorebirds and waterfowl used shallow ponds more than deeper ponds.

In marsh areas near wildlife impoundments, waterfowl, shorebirds, and other waterbirds preferred the large impoundments over the depauperate, man-made marsh ponds, possibly because impoundments may offer a greater diversity of prey, depth of water, and vegetation. With succession, man-made ponds may become more attractive to waterbirds as submerged aquatic plants become established. Caution should be exercised before allowing alteration of pristine wetland areas.

Seagrasses

The loss of seagrass beds reduces available habitats for wildlife. Studies in Texas and Louisiana by National Wetlands Research Center scientists have identified factors including salinity, light, and storms that limit the distribution and abundance of seagrasses, especially *Halodule*, a critical food for wintering redheads. Increased irrigation drainage flow from agricultural areas has increased freshwater flow to the Laguna Madre in Texas. This flow may explain why the Laguna is less hypersaline during drought periods and why it supports seagrasses that are less saline-tolerant and unimportant to redheads.

Personnel from the Environmental Protection Agency, National Oceanic and Atmospheric Administration, five Gulf Coast States, and the Center are developing the first comprehensive geographic data base on seagrass beds from Anclote Key, Florida, to the Texas–Mexican border.

Sociological Aspects of Habitat Negotiation

Required consultations for licenses and permits between resource management agencies (including the Fish and Wildlife Service) and project developers and operators are critical to the protection of wetland habitat. Negotiations concerning protection of species, species management, or mitigation are central to unavoidable habitat losses. Researchers at the National Ecology Research Center are studying these negotiation processes to determine what factors contribute to successfully negotiated consultations; what strategies and what sets of information (habitat quantification, economic and social value of resource recovery, recreational use values) are critical for effective negotiations.

Research has been conducted on Federal Energy Regulation Commission licensing by comparing case study projects in the Pacific Northwest and the Atlantic Northeast. Careful measurements have been made of several elements of the negotiation's success; the obligation to negotiate, the degree to which all parties are represented, the balance of power among parties; the clarity of technical issues, the sense of urgency to reach agreement, and each organization's commitment to implement the agreements reached.

Mississippi River Deltaic Plain

Although the rate of loss of wetlands in the Mississippi River Deltaic Plain has decreased, wetland loss in the delta still accounts for 80% of the annual coastal wetland loss in the United States. Coastal marshes and forested wetlands are at risk from human activities, natural compacting and sediment dewatering, and global sea level rise.

The Coastal Wetlands Planning, Protection, and Restoration Act of

1990 authorized up to $170 million over 5 years to restore and protect the Mississippi River Deltaic coastal wetlands. The act charged a Federal–State task force with developing and implementing a comprehensive wetlands plan. National Wetlands Research Center personnel provided technical support to the task force in the form of computer landscape models, geographic information system maps and data, and remote-sensing data. The information was needed to predict the effects of proposed wetland restoration and to develop basin-wide hydrologic management plans.

Specifically, in the Terrebonne and Barataria basins, the Center cooperated with landowners to construct three impounded research areas covering 283 ha for experiments to compare managed and unmanaged marshes. The Center also developed a computer model to predict habitat and basin-level changes in Barataria Bay, Louisiana. The model is being demonstrated at Jean Lafitte National Park, in a marsh-management site, and at four coastal restoration sites.

Coastal Barrier Resources System

One of the longest and best defined chains of coastal barriers in the world lies along the United States coastline of the Atlantic Ocean and Gulf of Mexico. This chain has more than 400 barriers (barrier islands, barrier spits, bay barriers, and tombolos) stretching along 4,345 km (2,700 miles) of shoreline. These coastal barriers both contain and protect natural resources of incredible value. Despite their value as scenic, scientific, recreational, natural, historic, and economic, these barriers are vulnerable to damage from development.

In recognition of the importance of these natural resources, the U.S. Congress enacted the Coastal Barrier Resources Act (CBRA) in 1982, thereby establishing the Coastal Barrier Resources System. The original system comprised 186 undeveloped and unprotected units or barriers totaling 182,115 ha (450,000 acres) and located along 1,078 km (670 miles) of Atlantic and Gulf shoreline.

The act made most Federal revenues that promote economic growth or development unavailable for use in the system. The philosophy behind the act was that risk associated with new development should be borne by persons choosing to live and work on the barriers, not by all United States taxpayers.

By restricting Federal expenditures and financial assistance on specific undeveloped coastal barriers, the Federal Government can minimize the loss of human life, reduce the wasteful expenditure of Federal revenues, and reduce the damage to fish and wildlife and other natural resources that can accompany development of these fragile areas.

The 1982 act directed the Department of the Interior to study the system and prepare for Congress a report with recommendations for changes in the original system, based on an evaluation of management alternatives that would foster conservation of the natural resources of the system.

Under the direction of the Assistant Secretary for Fish and Wildlife and Parks, the Coastal Barriers Study Group prepared the report. The group included representatives of the Fish and Wildlife Service, the National Park Service, the U.S. Geological Survey, and other Departmental offices. The group consulted with the U.S. Army Corps of Engineers, the Department of the Treasury, and the Federal Emergency Management Agency.

Personnel from the National Wetlands Research Center served on the committee and worked with other Fish and Wildlife Service personnel to produce draft reports, collate public comments, and produce a final report to Congress. The report, completed in 1988, consisted of 22 volumes, an executive summary, and 4 appendices.

The Center also acquired aerial photography of the Atlantic and Gulf coasts and developed photo atlases of the system as defined at that time. The first 5-year update was done in 1987. Additionally, in 1987 the Center produced, in cooperation with Louisiana Sea Grant, an educational extension brochure entitled *Restless Ribbons of Sand: Atlantic and Gulf Coast Barriers*. In 1990, Congress passed the Coastal Barrier Improvement Act, amending the 1982 act. The system now comprises 560 units totaling more than 505,815 ha (1.25 million acres) of barriers along the Atlantic and Gulf coasts, as well as along the coasts of Puerto Rico and the Virgin Islands in the Caribbean and along the shores of the Great Lakes.

The second 5-year update began in 1992. The Center is producing a set of photo atlases for Fish and Wildlife Service headquarters and for each Service Enhancement Office located along the coast, to assist personnel in accurately determining unit boundaries. In 1992, the Center completed the Puerto Rico and Virgin Islands atlases and acquired aerial photography, selected and enlarged photos, and began the atlases for the Atlantic and Gulf coasts. Atlantic and Gulf coast atlases will be completed in 1993; the Great Lakes atlas will be completed in 1994. The aerial photography is color infrared at a scale of 1:31,000 obtained from the National Aeronautics and Space Administration's High Altitude Mission Program. About 4,200 photographs are required for this project.

The Effects of Logging on a Montane Salamander

The Sacramento Mountain salamander is a Pleistocene relict, restricted to moist microhabitats above 2,500 meters in two small mountain ranges in south-central New Mexico. Most of its range is in the Lincoln National Forest. In experimental studies funded by the U.S. Forest Service and conducted by National Ecology Research Center personnel, populations of the Sacramento Mountain salamander persisted for up to 4 years after logging. Salamanders were found on all 16 permanent plots after various intensities of tractor and cable logging. Future studies will determine if the salamander can survive from the early stages of the logging cycle, when its forest litter habitat is exposed to the heating and drying effects of direct sunlight, until forest regeneration once again ameliorates the environment.

Education

The National Wetlands Research Center and the National Wetlands Inventory (NWI) helped produce *Coastal Wetlands of the United States: An Accounting of a Valuable National Resource*. This National Oceanic and Atmospheric Administration (NOAA) report describes a data base on the distribution and abundance of coastal wetlands in the contiguous United States. The National Wetlands Research Center, Louisiana Sea Grant, NWI, and NOAA, produced a companion report, *The Fragile Fringe: Coastal Wetlands of the Continental United States*.

Hazardous Waste Sites

Wetlands are virtually lost when they become contaminated from wastewater and hazardous chemicals. To understand the effects of contaminants on wetlands, scientists at the National Wetlands Research Center developed a data base to incorporate into a geographic information system. The location, structural composition, and quantity of contaminants at superfund and hazardous waste sites in Louisiana were recorded as abandoned, inactive, or active sites. Additional data bases (e.g., census, water well) were added to show proximity of various features to the hazardous sites. The Center presented the information in an atlas corresponding to U.S. Geological Survey 1:24,000- and 1:100,000-scale maps.

Contaminants

Heightened awareness of human effects on the global environment has resulted in widespread concern for protection of environmental quality. Identification of, protection from, and mitigation of harmful effects of environmental contaminants has long been a central mission of the Fish and Wildlife Service. Despite advances in the technology and understanding of hazard assessment, anthropogenic chemicals and activities continue to threaten wildlife. Research efforts in this arena provide scientific data and tools to facilitate maintenance of biological diversity, protection of trust resources and their supporting habitat, and balance of economic growth with ecological considerations.

Assistance Provided to Operational Contaminant Activities

Staff of the Patuxent Analytical Control Facility completed contaminant analyses on about 20,000 samples per year for all Fish and Wildlife Service regions. This included over 15,000 samples analyzed for the Exxon Valdez Natural Resource Damage Assessment. Over 1,000 Rapid-Turnaround samples were analyzed for law enforcement cases, endangered species incidents, and natural resource damage assessments. Over 115 Fish and Wildlife Service field stations have been linked to the Environmental Contaminant Data Management System, and more than 17,000 samples have been tracked using this computer system. Many samples were processed with cooperation of the National Wildlife Health Research Center, the Fish and Wildlife Forensics Laboratory, and the National Fisheries Contaminants Research Center.

Acid Deposition Effects on Nongame Migratory Birds and Their Habitats

Acid deposition increases the acidity of surface waters, and can increase concentrations and toxicity of some metals (e.g., aluminum). Biological effects include decreased species richness and species-specific toxicity in aquatic plants, invertebrates, fish, and amphibians. Acidification of lakes in the northeastern United States, eastern Canada, and northern Europe has generated concern about food chains for aquatic birds. Studies in Scandinavia suggest that aluminum has been responsible for reproductive failure of pied flycatchers nesting near acidified lakes.

Scientists at the Patuxent Wildlife Research Center fed captive European starlings diets containing graded concentrations of aluminum (basal control, 200 ppm, 1,000 ppm, and 5,000 ppm, normal calcium and phosphorus, low calcium and phosphorus, or low calcium and high phosphorus). Number of eggs laid, food consumption, and body weight were not affected by aluminum concentration. Low calcium decreased egg production and caused changes in egg size, egg weight, egg shell thickness, and femur strength. These results suggested that calcium deprivation in acidified aquatic habitats could adversely affect egg production and growth of young, and may pose a greater threat to birds than metal poisoning.

Food Webs and Contaminant Exposure of Migratory Nongame Birds

In San Francisco Bay, contaminant concentrations in ducks were higher than in their prey, and were suggestive of bioaccumulation. Elevated concentrations of certain metals, trace elements, organochlorine pesticides, and PCB's have also been detected in eggs of fish-eating birds, including black-crowned night-herons and snowy egrets. Deformed embryos and chicks, crushed eggs, and eggs that failed to hatch, conditions frequently produced by contaminants, were also observed. Because night-herons frequently nest and winter adjacent to San Francisco Bay, contaminants responsible for these reproductive problems were likely acquired within the estuary.

Insecticide Effects on Wetland Upland Wildlife

Application of broad-spectrum insecticides in routine agricultural practices and in response to insect outbreaks may directly and indirectly affect upland birds. In Minnesota, State-mandated control efforts in response to grasshopper outbreaks have resulted in spraying of broad-spectrum insecticides on non-cropped upland areas (e.g., roadsides and Conservation Reserve Program lands) that are critical for many songbirds and upland game birds. Some commonly used pesticides caused direct mortality in upland birds and many may indirectly affect birds by reducing or eliminating insects and other invertebrates that comprise the primary food source of young birds.

In 1991, scientists with the Minnesota Cooperative Fish and Wildlife Research Unit investigated the direct effects of three commonly applied insecticides on ring-necked pheasants and gray partridges in a controlled field experiment. Two cholinesterase-inhibiting insecticides and one pyrethroid insecticide were applied at recommended label rates to field plots where caged pheasants and partridge had been placed. Pheasants and gray partridges of three age classes (2 weeks, 6 weeks, and >14 weeks) were sprayed, and insects were sampled before and after spraying. No mortality of either pheasants or partridges resulted from direct exposure to any of the insecticides sprayed, nor was any impaired behavior seen that might have been caused by insecticide exposure.

Cytochrome P450 as a Biomarker of Contaminant Exposure

Research is under way to enable use of cytochromes P450 (P450's) induction in wildlife as a biochemical indicator of contaminant exposure in birds. The two major classes of inducers of P450's are the 3-methylcholanthrene-type (includes polycyclic aromatic hydrocarbons, dioxin, and coplanar PCB's and induces the IA family of P450's) and the phenobarbital-type (includes noncoplanar PCB's and some chlorinated pesticides such as DDT and its metabolites, and induces the IIB family of P450's).

Controlled studies were performed with mallards, black-crowned night-herons, and domestic rats treated with inducers of P450's, and field validation trials were conducted using pipping and nestling black-crowned night-herons. Analytical methods were developed to evaluate the P450 status in control and induced animals by assay of monooxygenase enzyme activities and by western blotting, a technique that combines electrophoresis and antibody binding. These techniques were applied to black-crowned night-herons collected from relatively undisturbed (Chincoteague National Wildlife Refuge in Virginia) and industrialized sites (Cat Island, Green Bay, Wisconsin, and Bair and West Marin islands in the San Francisco Bay, California). Tissue burdens of a variety of organochlorine contaminants were determined. For the pipping embryos, four monooxygenases were found highly correlated with PCB concentrations. This and other studies suggest that monooxygenase induction may serve as a rapid and inexpensive tool for screening contaminant samples before their submission for time-consuming and expensive residue analysis, and also provide important data on contamination of wetlands.

Agricultural Irrigation Drainwater

Conservation of aquatic migratory birds has been enhanced by recent research on agriculturally mobilized selenium. When research on agricultural irrigation drainwater was initiated nearly a decade ago, it was believed that waterborne selenium concentrations in the 100's of ppb range were required to pose a potential hazard to wildlife. Controlled studies at the Patuxent Wildlife Research Center, and field research in the Tulare Basin in central California and elsewhere by Center scientists, have shown that less than 1 ppb of waterborne selenium can lead to excessive bioaccumulation in wildlife.

Predictive relations allowing wetland managers to assess the potential for wildlife hazards based on concentrations of waterborne selenium have been developed and field validated. Research on agricultural irrigation drainwater has significantly advanced the Fish and Wildlife Service's goal to restore, enhance, manage, and protect wetlands.

Acid Deposition Effects on Waterfowl and Supporting Habitat

The potential effects of acidification on waterfowl habitat and recruitment were investigated by researchers at the Patuxent Wildlife Research Center using a complex of 24 man-made 0.03-ha aquatic mesocosms. Ponds were treated with sulfuric acid and aluminum sulfate to yield four regimens, including pH 6.5–7.0 (CONTROL), pH 6.5–7.0 with added aluminum (AL), pH 4.8–5.3 (ACID), and pH 4.8–5.3 with aluminum (ALAC). Biological measurements included abundance and species composition of aquatic plants, benthic invertebrates, and tadpoles.

American Black duck broods were raised on the ponds to determine if changes in the abundance, species composition, or metal content of their food base impair their growth and survival. Cricket frogs and gray tree frogs were found especially sensitive to acidification of the mesocosms.

Acidification also reduced the total plant cover on the ponds and the relative cover for bladderwort and spike rush. Preliminary analysis of invertebrate data indicated that snails were virtually eliminated and that the number of dragonfly nymphs was greatly reduced in acidified ponds. If abundance of other aquatic invertebrates followed this pattern, waterfowl using acidified ecosystems would have problems obtaining sufficient food for normal growth and development.

Esfenvalerate and Brood-rearing in Mallards

Degradation of wetland quality by pesticides may disrupt waterfowl production. In 1991, biologists at the Minnesota Cooperative Fish and Wildlife Research Unit conducted a study of ducklings imprinted to human observers in Fish and Wildlife Waterfowl Production Areas in Minnesota that were treated with esfenvalerate. Weight gain by ducklings and the number of aquatic invertebrates were decreased for about 2 weeks after pesticide application. Such reduced growth might compromise duckling survival.

Estuaries and Contaminants in Food Webs

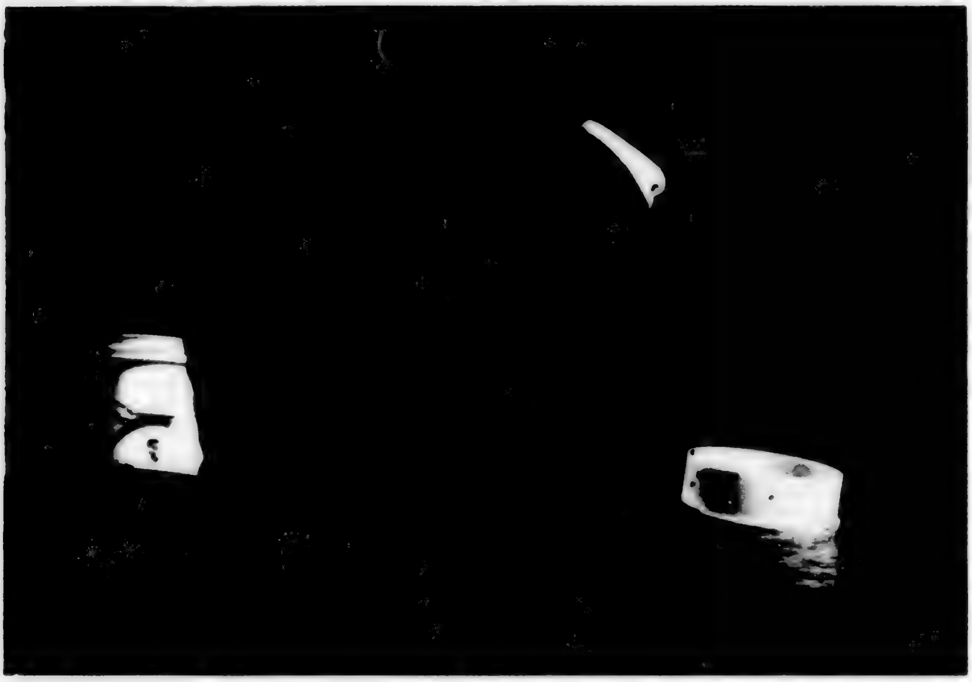
A community-oriented study of contaminants in prey of aquatic birds in the San Francisco and Chesapeake bays was undertaken by the Fish and Wildlife Service. The relation of time of year and geographical location to contaminant burdens in food webs was examined. In addition, the relations among site-specific contaminant concentrations and invertebrate community diversity, invertebrate fitness, and contaminant burdens in waterfowl and their prey were studied. The metal concentrations of five invertebrate and one algal species found in both bays were high and exceeded laboratory bioassay thresholds to trigger sublethal or lethal effects. Of the metals quantified in six species, 46% of the concentrations were higher in San Francisco Bay, 44% of the values were similar between bays, and 12% of the concentrations were higher in the Chesapeake Bay. No relatively clean site was found. In general, concentrations of cadmium, mercury, and selenium were highest in San Francisco Bay, while lead levels were highest in Chesapeake Bay. Arsenic, cadmium, and selenium concentrations were highest in the northern portion of San Francisco Bay, while lead and mercury values were highest in the southern region. Contaminant concentrations in clams in both bays were inversely related to their caloric values.

Contaminant Effects on Disease Susceptibility and Immune Function

Scientists from the National Wildlife Health Research Center have studied the effects of contaminants on immune function and disease resistance. Mallards exposed to lead through natural ingestion and by dosing of shot showed significant decreases in immune function blood parameters and ability of the spleen to produce antibodies. In another study, mallards were hatched and reared on experimental mesocosms receiving water containing 0, 10, and 30 ppb selenium. At 21 days of age, birds were challenged with Duck Virus Hepatitis. Mortality rate was directly related to selenium concentration. These studies suggest that contaminants may increase disease susceptibility.

Bald Eagle Mortality Caused by Organophosphorus and Carbamate Pesticides

National Wildlife Health Research Center necropsy records revealed the poisoning of 80 bald eagles by organophosphorus and carbamate insecticides from 1982 through 1991. Poisonings were found in 19 States, and the com-



Service biologist searches for shellfish in tidal mudflats of San Francisco Bay. Collecting can be a dirty job! *Photo by K. King.*

pounds most frequently involved were famphur (38 cases) and carbofuran (24 cases). Data for carbofuran were instrumental to the Environmental Protection Agency in rendering a decision to phase out the sale and use of granular formulations of carbofuran.

Microgold Mining, Cyanide, and Wildlife

During the 1970's, gold prices soared from about $35 to over $350 an ounce, while cyanide processing technologies improved to permit the economical extraction of as little as 0.02 ounce of gold from a ton of low-grade ore. These technologies use cyanide solutions held in ponds up to 500 acres in size. Application of the technology is widespread, and in Nevada 300 such ponds exist. Ponds in the Great Basin and other arid areas attract birds, especially during spring and fall migrations. Since 1989, researchers at the National Wildlife Health Research Center have diagnosed cyanide poisoning in 35 species of migratory birds recovered from 27 incidents associated with mining. Mortality was found in 5 States at 14 mining operations. Waterfowl, shorebirds, and songbirds were at high risk, but gulls, doves, raptors, pelicans, and loons also succumbed. Mortality of resident birds, mammals, amphibians, and reptiles was also reported with losses of several thousands of animals at a single mine in 1 year. It is likely that many losses go unreported or undetected.

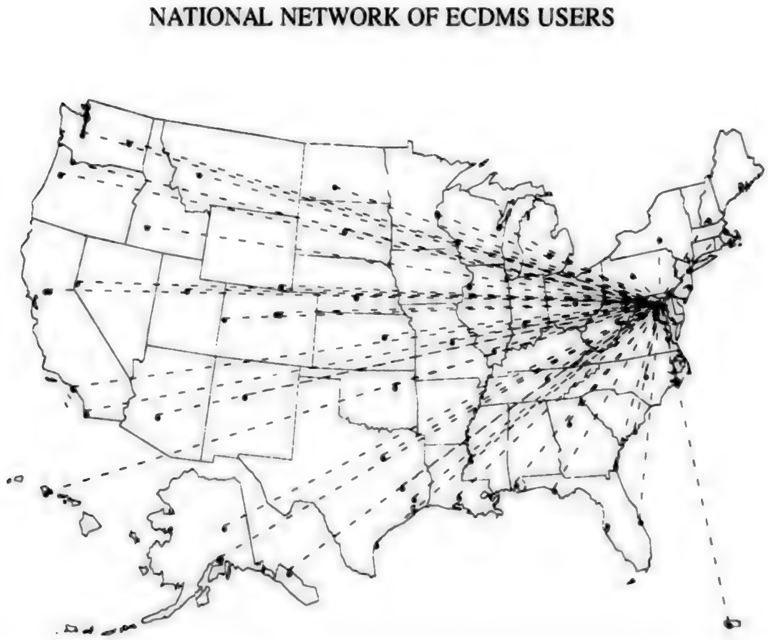
Field studies by staff of the Patuxent Wildlife Research Center characterized cyanide concentration gradients in tailings ponds and evaluated bird use and responses. In large ponds, a cyanide gradient, differing by a concentration factor of two to three, can result in varying degrees of exposure depending on where attracted birds land on the pond. Ducks can succumb in 30 min after landing and drinking water near the discharge end of a pond, but at the upper end of the same pond no problems may be apparent.

Puddling of cyanide solutions on tops of the heaps, and the resulting attraction and possible mortality of migratory birds is also of concern. Of the 30 heap-leach mining operations seen during an April 1991 aerial survey, 24 (80%) had at least one apparently active (wet) heap. Although few birds were seen on tops of the heaps during short visits averaging about 2 h, dead birds were found at 2 of the 19 mines (11%). Controlled field studies are needed to define a safe concentration of cyanide.

Contaminant Hazard Reviews

Contaminant Hazard Reviews were initiated by Research and Development in 1985, in response to requests from Fish and Wildlife Service environmental specialists for information on selected contaminants. The report format and choice of subject was a continuing cooperative venture of the operational Regions,

During Fiscal Years 1990 and 1991, the National Wildlife Health Research Center provided diagnostic services to Federal, State, and other personnel throughout the United States and Territories. The U.S. Fish and Wildlife Service submitted 59% of the specimens examined, and State and local agencies submitted 33%. Although all Regions requested diagnostic assistance, Region 3 was the most frequent user with 27% of total submissions. *Photo by J. Runningen.*



National network of Environmental Contaminant Data Management System Users.

system's primary function was as a data base that stored and transmitted information about the samples to be analyzed through the Patuxent Analytical Control Facility and the results of those analyses. The innovation will become an invaluable resource for the contaminants program.

Health

Wildlife Mortality

Scientists from the National Wildlife Health Research Center responded to 381 reports of wildlife mortality that were found in the United States and Canada during the biennium. Losses from the three primary causes of disease outbreaks–avian botulism (type C), toxin exposure, and avian cholera–were in excess of 227,000 birds.

Botulism type C was widespread with 104 outbreaks in 28 States accounting for the death of an estimated 104,000 birds. About half of the recorded mortality was found in Utah in connection with the receding Great Salt Lake. Botulism

Vaccination of free-living wildlife against disease is a management concept that is receiving increased attention. Researchers at the National Wildlife Health Research Center are testing the effectiveness of a vaccine against avian cholera, developed for the Aleutian Canada goose, in other waterfowl species. Feasibility studies are underway to develop a means of mass-vaccination of waterfowl against this disease. *Photo by J. Runningen.*

outbreaks continued to be found in previously unaffected sites, including an area in Colorado where 7,000 waterfowl died.

Avian cholera was found in 12 States with known losses of almost 68,000 birds. The States with the highest incidence of avian cholera were California, Texas, Nebraska, and Minnesota. The number of areas experiencing outbreaks of this disease continues to increase; Minnesota had its second reported outbreak in 1991; and in Texas, losses of close to 10,000 were found during the biennium. Reports of avian cholera are also increasing from breeding grounds. The disease is suspected to have killed 5,000 geese on the breeding grounds on the Outer Banks of Canada during spring, 1991. Although the mechanisms initiating a cholera die-off are unknown, scientists with the South Dakota Cooperative Fish and Wildlife Research Unit suggest that mycotoxins may enhance waterfowl susceptibility to this disease.

Exposure to man-made toxins may have caused 54 die-offs in 24 States. Most die-offs were found following bird use of chemically treated lawns, public lands, and agricultural fields.

Several independent events resulted in significant bird losses. An estimated 150,000 grebes died of an as yet undetermined cause during spring, 1992 in southern California. In Alberta, Canada, at least 7,200 cormorants, pelicans, and gulls died of Newcastle Disease virus. This was the first known, large scale, epizootic of Newcastle Disease in free-flying wild birds.

Two other diseases, salmonellosis and duck plague, were found at an unexpectedly high frequency. Salmonellosis was reported in 12 States, generally where human contact occurs, including backyard bird feeders. Duck plague was confirmed or suspected in 11 die-offs that were confined to domestic or game-farm reared waterfowl. Fortunately, rapid implementation of aggressive and thorough disease control measures prevented the spread of duck plague to wild, free-ranging waterfowl.

Reovirus in Woodcock

During winter, 1989–90, a die-off of about 1,000 American woodcock was found in New Jersey and Virginia. Scientists at the National Wildlife Health Research Center isolated a reovirus from various vital organs. Reoviruses cause disease and mortality in domestic avian species; however, their effect on wildlife species is unknown. A survey of woodcocks collected near the site of the die-off was initiated to assess the prevalence of reoviruses in free-living woodcocks. Presence of the virus could show that the virus isolations from dead birds represented merely a carrier state. The lack of viral isolates from the collected birds supported the circumstantial evidence that the reovirus isolated in 1990 was associated with the woodcock mortality.

Trumpeter Swan Mortality

During winter, 1991–92, a large portion of the 36 trumpeter swans at Fish Springs National Wildlife Refuge, Utah died. These swans were part of the translocation project to expand the limited Rocky Mountain trumpeter swan population. The National Wildlife Health Research Center dispatched a field team to investigate the die-off. Fourteen carcasses were recovered; 11 were suitable for necropsy, and a *histomonas*-like protozoan parasite was found responsible for the deaths. Eight swans that had not yet succumbed to the disease were destroyed to prevent their migration and possible spread of the disease to the 2,000 other trumpeter swans in the Rocky Mountain population. Six of the destroyed swans either had visible lesions or infection. Tundra swans and other waterfowl at Fish Springs NWR were not affected, nor were any trumpeters at any of the other six translocation sites. The decision was made to suspend any translocations of trumpeter swans to Fish Springs.

Health Certification of Captive-raised Waterfowl

The disease risks posed by released captive-reared waterfowl are increasingly of concern to the Fish and Wildlife Service because free-ranging waterfowl populations are at unacceptably low levels. Accordingly, wildlife disease specialists at the National Wildlife Health Research Center are helping to develop a health certification program for wildlife translocated to, or released on, public lands.

Brucellosis at the National Elk Refuge

Serological evidence indicates brucellosis is common in elk fed at the National Elk Refuge and 22 other feeding grounds managed by the State of Wyoming. This is a source of concern among livestock interests who fear the potential risk of transmission of this disease to cattle. While the exact risk is unknown, the issue is sufficiently contentious to generate litigation procedures. Expertise at the National Wildlife Health Research Center serves as a resource on this issue as well as providing direct technical assistance to the National Elk Refuge staff. Further, the Service is a member of the ad-hoc technical committee on brucellosis in the Greater Yellowstone Ecosystem.

Some elk on concentrated feeding grounds carry brucellosis. The National Wildlife Health Research Center is working with managers to assess the risk to domestic stock in the vicinity. *Photo by B. O'Gara.*

Wildlife Disease Training Program

Federal Aid funding at the National Wildlife Health Research Center provided resources for training State conservation departments in the recognition and mitigation of wildlife diseases. This funding augmented resources used to provide similar training to Federal wildlife managers and biologists. During the last biennium, 14 wildlife disease workshops were conducted for State and Federal personnel. These workshops were generally 2-day events covering recognition of diseases, where and how to get assistance, and what to do to control disease outbreaks. States receiving technical assistance through the workshop program included Arizona, Hawaii, Kansas, Louisiana, Maine, Minnesota, Mississippi, New Hampshire, Tennessee, Vermont, and Wisconsin.

Considerable effort was expended to develop and produce training videos. Two completed videos covered *Blood Collection from Birds* and *Biological Sample Collection*. Live demonstration and step-by-step information were provided in the videos to guide the proper collection of biological materials essential in the diagnosis of wildlife mortality. A third video, *Postmortem Procedures for Ungulates*, illustrated how to conduct a thorough postmortem examination of large ruminants. A fourth video, *Field Investigation of Wildlife Mortality*, was designed to provide basic guidance on disease investigation (epidemiology) techniques.

Training was also provided to visiting students (externs) and scientists. Nine senior-level veterinary students from six States and one Canadian province completed a 4–6-week preceptorship rotating through necropsy, diagnostic laboratories, and research projects during the last biennium. Scientists from the former Soviet Union and India have visited the Center for varying lengths of time to study wildlife disease problems applicable to their countries.

Hawaiian Forest Bird Diseases

A large proportion of forest birds native to the Hawaiian Islands have become endangered or extinct since European settlement. Several potential causes have been identified, including diseases introduced by settlers. Researchers at the National Wildlife Health Research Center Hawaii Volcanoes Field Station, established in 1991, are determining the role of diseases, particularly avian malaria and avian pox, in limiting the distribution and abundance of native forest birds. They are investigating the distribution of these two diseases in both native and introduced birds, and the distribution of the introduced Culex mosquito, the primary vector of avian malaria. Knowledge about the effect of these and other diseases on native forest birds will help guide habitat acquisition and other management strategies to help their population recovery. In addition, disease investigators at a second field station in Honolulu are assisting State and Federal resource agencies in wildlife disease outbreaks throughout the Pacific Islands.

Wetland Sediment Conditions Associated with Avian Botulism Outbreaks

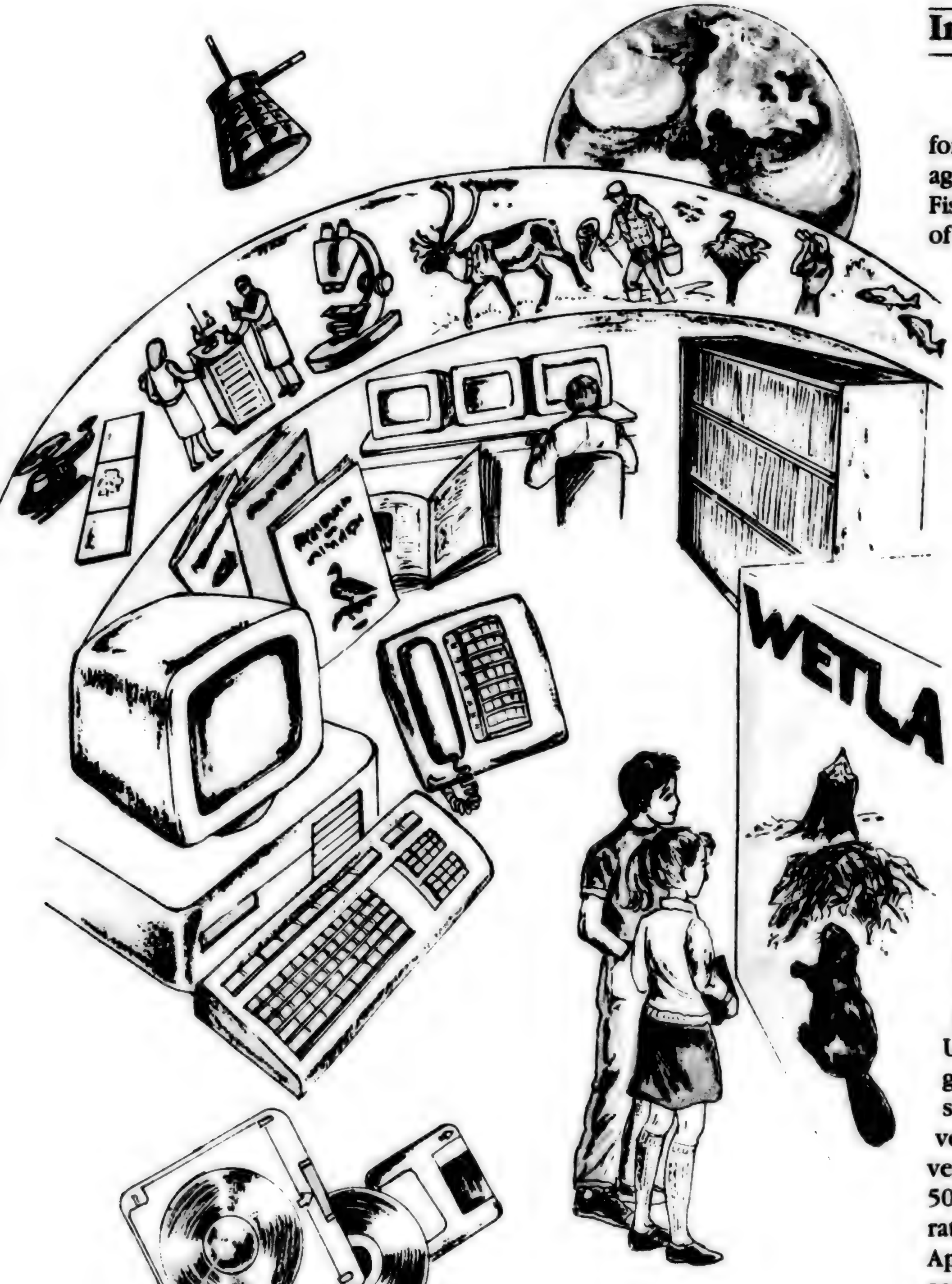
Avian botulism, caused by ingestion of toxin produced by the bacterium *Clostridium botulinum*, kills thousands of birds yearly in wetlands throughout the continent. The bacterium is a common inhabitant of wetland sediments and can be found year-around. The disease is found only seasonally, primarily during summer and fall, and not every year in the same wetland. In addition, botulism is never found in some wetlands, even though the organism is known to be abundant. Environmental conditions that favor botulism outbreaks are poorly understood but are thought to be related to wetland sediment characteristics and water management.

Research conducted by scientists at the National Wildlife Health Research Center at one wetland complex, Sacramento National Wildlife Refuge in California, suggested that botulism outbreaks were more likely to be found in wetlands with elevated sediment temperature, pH, conductivity, and oxidation-reduction potential. More recently, field studies at refuges in northern California and Montana support this hypothesis. Additional research is under way to verify these observations, including work at other field sites and in the laboratory. An understanding of these environmental factors and their role in triggering botulism outbreaks might lead to wetland management strategies that reduce the risk of avian botulism.

Remote Sensing

National Wetlands Research Center scientists investigated using high-spectral resolution remote-sensing data to identify and monitor stress in wetlands. Preliminary analysis of canopy structure and spectral reflectance of marsh types in Louisiana and Florida and forested wetlands in the Yazoo Basin in Mississippi indicated that the method works. Regrowth of Juncus and Panicum marshes after a burn can be monitored quantitatively by the use of a ceptometer on the ground or remotely with a spectral radiometer. Ground-based measures of Leaf Area Index (as estimated by ceptometer measurements) are related to spectral signatures recorded from a helicopter-based radiometer at a 152-m altitude. The radiometer data consist of a scan identifying reflectance values from the range of 400 to 1,100 nm of the electromagnetic spectrum (blue visible to middle infrared). This spectral signature is used to identify which range of the spectrum (or which band of a satellite sensor) is appropriate to differentiate zones between and within vegetation types and vegetation change over time.

Sharing Scientific Information



Information Transfer

Timely sharing of scientific information for better resource management is vital to the mission of the Fish and Wildlife Service. The Office of Information Transfer–Fort Collins specializes in communication of scientific information to the ultimate benefit of the resources the Fish and Wildlife Service is charged to protect.

The Office of Information Transfer responds to the information needs of the natural resource community by editing or publishing manuscripts written by Service employees, by providing references to the literature on topics of interest, and by providing information or expertise to field biologists about challenging fish or wildlife resource problems.

Critical to information transfer is the continued compilation of references to the scientific literature provided by ***Wildlife Review*** and ***Fisheries Review***. Approximately 45,000 citations were added to these data bases in FY 91–92, including theses and dissertations from United States universities offering graduate programs in natural resources. The data bases were converted to compact disk by a private vendor, who agreed to provide a 50% discount on the subscription rate to the Fish and Wildlife Service. Approximately 3,000 Selective Dissemination of Information packages (customized bibliographic updates) were sent to Service personnel in response to ongoing information needs of the Fish and Wildlife Service. The process of acquiring citations from symposia proceedings was formalized, with several hundred reports being received for inclusion into the data bases. Over 150 new exchanges of information were established with research centers around the world.

Research Liaison Function

The key to effective information transfer is two-way communication, so Office of Information Transfer staff attend regional and national meetings of functional groups of the Service to be better informed of local and national issues affecting Fish and Wildlife Service operations. Staff participated in coordination meetings that took place between Research and Development and the other regions, and presented information about office capabilities and services to audiences in Law Enforcement, Fish and Wildlife Enhancement, and Refuges and Wildlife. In an effort to improve communications within Research and Development, a slide show on the Office of Information Transfer was developed and presented at four centers in FY 92. A separate show emphasizing the Fish and Wildlife Service's publication process was presented at two centers.

Approximately 350 requests from Fish and Wildlife Service operations for technical assistance were addressed each year. Routine assistance was provided by referring personnel to scientists having expertise on particular topics or by searching the *Wildlife Review/Fisheries Review* database. Significant technical assistance provided in FY 92 included helping to develop a comprehensive plan for managing neotropical migrants in the Southwest Region, participating in a work group for the new contaminants biomonitoring program, reviewing and analyzing an air dispersion model for a national wildlife refuge, consulting and assisting in cattail management on a national wildlife refuge, and searching and summarizing of literature on important topics involved in the development of a programmatic Environmental Impact Statement for the Division of Refuges.

Special Projects

More than a dozen workshops were developed or coordinated in FY 91–92 to meet the needs of the regions and to showcase research results. Topics included effects of disturbance on national wildlife refuges, management for biological diversity, management for coastal nongame species, impacts of zebra mussels on native unionids, management for migrating and wintering waterfowl, and use of biological farming practices on refuges. These workshops included presentations by Research and Development scientists representing a range of expertise.

Development of the *Waterfowl Management Handbook* continued, as 10 new chapters on waterfowl or wetlands ecology and management were completed and distributed. For the first time, one chapter included computer software, which was developed by the Missouri Cooperative Fish and Wildlife Research Unit and the National Ecology Research Center. The software allowed managers to use regression formulas to estimate seed yields for moist soil management fields.

A prototype database using RBase was developed in response to the need identified in three regions for information on neck collars for geese. In direct response to a need identified by the Northwest Region, the Office of Information Transfer worked with the Washington Cooperative Fish and Wildlife Research Unit to develop a database of waterbirds in Puget Sound. On behalf of the Southwest Region, the Office of Information Transfer worked with the Texas Cooperative Fish and Wildlife Research Unit to complete a DNA library for the endangered Attwater's greater prairie-chicken. A handbook of field techniques was prepared for use by staff of the Attwater Prairie-Chicken National Wildlife Refuge.

Because Research and Development facilities are geographically dispersed throughout the country, and research centers have diverse responsibilities, the concept of Research and Development as a unified Region can be difficult to grasp. A packet containing separate brochures for each of the 13 research centers and the Office of Information Transfer was developed, produced, and distributed in FY 91 to meet information requests. Feature articles highlighting research accomplishments were prepared in consultation with the centers for publication in each issue of the *Fish and Wildlife News*.

The Office of Information Transfer met its responsibilities for local outreach in an innovative way in FY 92. In partnership with a local hands-on science museum, the Office of Information Transfer designed and built 12 interactive displays illustrating wetlands values. The exhibits attracted 14,000 visitors during 7 months of display in a local shopping mall.

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Directory

Directory of Research and Development facilities and personnel (as of October, 1992)

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NOTE: The mention of trade names does not constitute endorsement or recommendation for use by the Federal Government.

MARCH 3, 1849

UNITED STATES DEPARTMENT OF THE INTERIOR

Bruce E. Babbitt, Secretary

Fish and Wildlife Service
Region 8–Research and Development

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fishes and wildlife, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and attempts to assure that their development is in the best interests of all our people. The Department also has a major responsibility for Native American reservation communities and for people who live in island territories under U.S. administration.

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